PB81-108003

Volatilized Lubricant Emissions from Steel Rolling Operations

Pacific Environmental Services, Inc.
Santa Monica, CA

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

May 80

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-80-105	2.	3. RECIPIENT'S ACCESSION NO. PB81 10800 3
4. TITLE AND SUBTITLE Volatilized Lubricant Emissions from Steel Rolling Operations		5. REPORT DATE May 1980
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) C.J. Mackus and K.N. Joshi		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Pacific Environmental Services, Inc. 1930 14th Street Santa Monica, California 90404		10. PROGRAM ELEMENT NO. 1AB604
		11. CONTRACT/GRANT NO. 68-02-2606, Task 14
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Final; 4/78-4/79
		14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES IERL-RTP project officer is John S. Ruppersberger, Mail Drop 62, 919/541-2733.

16. ABSTRACT The report gives results of a study of the volatilization of lubricants used in steel rolling. Data from nine steel mills were used to: define the volatilized portion of lubricants used in rolling; and prepare total oil, grease, and hydraulic material balances for actual and typical cold and hot rolling operations. Air Pollution from cold and hot rolling was estimated from data acquired from questionnaires, plant visits, and emission source sampling. Introductory and background information on steel rolling, lubrication practices, rolling mill lubricants, and rolling emulsion application techniques is also presented. Study results generally agree with those of a previous study which estimated that for a typical integrated steel plant, with a raw steel production capacity of 3.6 million metric tons per year, 6530 metric tons per year of oils, greases, and hydraulic fluids are used throughout the plant. Since about 83% of these lubricants are used in steel rolling and finishing, this study concentrated on these operations. For a typical cold strip mill, total hydrocarbon (HC) emissions were estimated to be 358 metric tons per year. Therefore, the total HC emission rate for all cold strip mills in the U.S. is an estimated 7160 metric tons per year. It was also estimated that for a typical hot strip mill, total HC emissions were 94.7 metric tons per year (2460 metric tons per year for all US hot strip mills).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Hydrocarbons	Pollution Control	13B	07C
Lubricants		Stationary Sources	11H	
Hydraulic Fluids		Steel Rolling		
Steel Plants			13I	
Rolling Mills				
Vaporizing			07D	

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

PB81-108003

EPA-600/2-80-105

May 1980

Volatilized Lubricant Emissions from Steel Rolling Operations

by

C.J. Mackus and K.N. Joshi

Pacific Environmental Services, Inc.
1930 14th Street
Santa Monica, California 90404

Contract No. 68-02-2606
Task No. 14
Program Element No. 1AB604

EPA Project Officer: John S. Ruppersberger

Industrial Environmental Research Laboratory
Office of Environmental Engineering and Technology
Research Triangle Park, NC 27711

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington, DC 20460

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

DISCLAIMER

This report has been reviewed by the Industrial Environmental Research Laboratory (RTP), U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

This report presents the results of an investigation of the volatilization of lubricants used in steel rolling operations. Data from nine steel rolling operations were used to: (1) define the volatilized portion of lubricants used in rolling operations; and (2) prepare total oil, grease, and hydraulic fluid material balances for actual and "typical" cold and hot rolling operations. Estimates of the air pollution resulting from both cold and hot rolling processes were made from data acquired by questionnaires, mill visits, and emission source sampling. Introductory and background information pertaining to steel rolling operations, lubrication practices, rolling mill lubricants, and rolling emulsion application techniques are also presented.

The results of this study were in general agreement with a previous study which estimated that for a typical integrated steel plant, with a raw steel production capacity of 3.6 million metric ton per year (4 million ton/year), 6,530 metric ton per year (7,200 ton/year) of oils, greases, and hydraulic fluids are used throughout the plant. Since approximately 83 percent of these lubricants are used in the steel rolling and finishing operations, this study concentrated on these operations. It was estimated that for a typical cold strip mill, total hydrocarbon emissions were 358 metric ton per year (395 ton/year). Therefore, the total hydrocarbon emission rate for all cold strip mills within the U.S. is estimated to be 7,160 metric ton per year (7,900 ton/year). It was also estimated that for a typical hot strip mill, total hydrocarbon emissions were 94.7 metric ton per year (104 ton/year) or 2,460 metric ton per year (2,700 ton/year) for all hot strip mills within the U.S. It was also estimated that of the total quantity of oil, grease, and hydraulic fluid used by the various rolling operations, approximately 12.5 percent of the lubricants purchased will enter the environment as air pollution.

ACKNOWLEDGEMENTS

To assist in the performance of the project and to provide additional sources of lubricant usage and fate information, a consultant was contracted by PES. PES recognized the need for a consultant with experience in the steel industy and a knowledge of the fates of steel mill lubricants. Richard Jablin was selected by PES and contracted to provide information and assistance in the area of material balance estimation and the fate of steel mill lubricants. Formerly with the Bethlehem Steel Corporation and Alan Wood Steel Company, Mr. Jablin served in a number of positions including Plant Engineer, Manager of Engineering and Construction, Director of Environmental Control. Since 1975, he has been self-employed as a consultant to the steel industry and has assisted in several EPA studies. He is a member of the Association of the Iron and Steel Engineers (AISE), and is a past Chairman of the Steel Committee of the Air Pollution Control Association (APCA).

Mr. Jablin supplied PES with technical advice concerning the operations of individual mills. He also assisted in the selection of rolling mills to be sampled, and the preparation for the sampling program. Further, he participated in the Inland Steel Indiana Harbor Works and U.S.S. Gary Works plant visits prior to the actual sampling trip.

Also, PES would like to thank the following steel companies for their participation in this project:

United States Steel Corporation
Inland Steel Company
National Steel Corporation
Wheeling Pittsburgh Steel Corporation
Florida Steel Corporation

TABLE OF CONTENTS

Section Page

ABSTRACT iii
ACKNOWLEDGEMENTS iv
LIST OF FIGURES viii
LIST OF TABLES x
CONVERSION FACTORS xii

1.0 INTRODUCTION 1-1

2.0 PROCESS AND EQUIPMENT DESCRIPTION 2-1

  2.1 Hot Roll Production Processes 2-1

    2.1.1 Equipment Utilizing Oil, Greases, or Hydraulic Fluids 2-7
    2.1.2 Use of Rolling Oils 2-8
    2.1.3 Wastewater Considerations 2-10

  2.2 Cold Roll Production Processes 2-11

    2.2.1 Equipment Utilizing Oil, Greases, or Hydraulic Fluids 2-16
    2.2.2 Use of Rolling Oils 2-17

3.0 DATA COLLECTION 3-1

  3.1 Questionnaire Preparation and Survey Design . . . 3-1
  3.2 Contacts and Responses 3-3
  3.3 Plant Visits and Interviews 3-6
  3.4 Sampling Program 3-7

4.0 HYDROCARBON SAMPLING AND ANALYSIS 4-1

  4.1 Inland Steel Indiana Harbor Works 4-1

    4.1.1 Sampling Train 4-2
    4.1.2 Sampling and Data Collection 4-2
    4.1.3 Data Analysis 4-5
    4.1.4 Grab Samples 4-7
    4.1.5 Laboratory Analysis 4-8

TABLE OF CONTENTS (CONTINUED)

Section Page

4.2 United States Steel Gary Works 4-12

4.2.1 Fugitive Hydrocarbon Emission Sampling . . 4-12
4.2.2 Hydrocarbon Emissions from 84 Inch Hot Strip Mill Finishing Stand Area 4-14
4.2.3 Grab Samples 4-22
4.2.4 Chemical Analysis 4-23

4.3 Laboratory Simulation of Rolling Oil Volatilization 4-24

4.3.1 Equipment 4-26
4.3.2 Procedure 4-26
4.3.3 Discussion of Results 4-26

5.0 DATA ANALYSIS 5-1

5.1 Methodology for Data Analysis 5-1
5.2 Factors Affecting Lubricant Usage and Fate 5-1
5.3 Inland Steel, East Chicago, Indiana 5-7

5.3.1 80 Inch Five-Stand Tandem Cold Reduction Mill 5-9
5.3.2 56 Inch Four-Stand Tandem Cold Reduction Mill 5-14
5.3.3 80 Inch Six Finishing Stand Hot Strip Mill 5-18

5.4 U.S. Steel, Gary Works, Indiana 5-22

5.4.1 80 Inch Five-Stand Tandem Cold Reduction Mill 5-22
5.4.2 84 Inch Seven-Stand Hot Strip Mill 5-26
5.4.3 84 Inch Seven-Stand Hot Strip Mill 5-32

5.5 National Steel, Ecorse Works at Detroit 5-37

5.5.1 80 Inch and 93 Inch Cold Reduction Mills Area 5-40
5.5.2 80 Inch Seven Finishing Stand Hot Strip Mill 5-45

5.6 Wheeling-Pittsburgh Steel Corporation, Steubenville Plant 5-48

5.6.1 80 Inch Six Finishing Stand Hot Strip Mill 5-51

TABLE OF CONTENTS (CONTINUED)

Section | Page

6.0 TYPICAL MILL 6-1

    6.1 Typical Cold Strip Mill (Cold Reduction Operation) 6-6

        6.1.1 Consumption of Lubricants, Oils, Greases, and Hydraulic Fluids 6-6
        6.1.2 Material Balance Loss Terms Estimate . . . 6-8

    6.2 Typical Hot Strip Mill (Hot Reduction Operation) . 6-10

        6.2.1 Consumption of Lubricants, Oils, Greases, and Hydraulic Fluids 6-10
        6.2.2 Material Balance Loss Terms Estimates . . . 6-14

7.0 DATA SUMMARY AND GENERALIZATIONS 7-1

8.0 RECOMMENDATIONS FOR ADDITIONAL STUDY 8-1

    8.1 Photochemical Reactivity of Volatilized Lubricants in Various Rolling Operations 8-1
    8.2 Hydrocarbon Emissions From Specific Processes . . 8-2

        8.2.1 Continuous Casting 8-2
        8.2.2 Hot Strip Mills 8-3

    8.3 Wastewater Sampling and Oil Analysis 8-4

9.0 REFERENCES 9-1

10.0 BIBLIOGRAPHIES 10-1

APPENDIX A TYPICAL LUBRICATING OILS USED BY VARIOUS STEEL COMPANIES

APPENDIX B HYDROCARBON STACK SAMPLING AND AMBIENT MONITORING ANALYSIS

LIST OF FIGURES

Figure Page

1-1 World Crude Steel Production 1-2
1-2 Percentage Consumption of Various Lubricants 1-3
2-1 Typical Cross-Section of Slab, Bloom, and Billet 2-2
2-2 Various Rolling Mill Configurations 2-4
2-3 Typical Cold Mill Arrangements 2-13
2-4 Diagram of the Roll Bite 2-15
2-5 Four-High Tandem Mill With Direct Application of Rolling Oil 2-19
2-6 Rolling Oil Applied As an Emulsion (Flooding) 2-20
2-7 Schematic of Recirculating Lubrication System 2-21
4-1 Five-Stand Tandem Cold Strip Mill Air Evacuation System (80 Inch Mill) 4-3
4-2 Stack Sampling Train and HC Analyzer 4-4
4-3 Gas Sample Tubes for Collection of Sample by Displacement 4-9
4-4 84 Inch Hot Strip Mill, Gary Works 4-13
4-5 Hot Strip Rolling Mill Parameters Across Finishing Stands 4-16
4-6 Rolling Oil Volatilization Lab Simulation Collection Apparatus 4-27
5-1 Basic Components of Rolling Mill Oil Mass Balance . . . 5-3
5-2 Cold Strip Mill Lubrication Mass Balance 5-11
5-3 Cold Strip Mill Lubrication Mass Balance 5-16
5-4 80 Inch Hot Strip Mill Not Utilizing Rolling Oils . . . 5-27
5-5 Cold Strip Mill Lubrication Mass Balance 5-28
5-6 84 Inch Hot Strip Mill Not Utilizing Rolling Oils . . . 5-33
5-7 84 Inch Hot Strip Mill Utilizing Rolling Oils 5-38
5-8 National Steel Great Lakes Division 80 Inch Five-Stand Tandem Cold Mill 5-42

LIST OF FIGURES (CONTINUED)

Figure		Page
5-9	Cold Strip Mill Lubrication Mass Balance	5-44
5-10	80 Inch Hot Strip Mill Utilizing Rolling Oils	5-49
5-11	Hot Strip Mill Not Utilizing Rolling Oils	5-55
6-1	Typical Cold Strip Mill Lubrication Mass Balance	6-12
6-2	Hot Strip Mill Not Utilizing Rolling Oils	6-18
6-3	Hot Strip Mill Utilizing Rolling Oils	6-20

LIST OF TABLES

Table		Page
2-1	Sheet and Strip Dimension Parameters	2-6
4-1	Stack Test Data Analysis Summary	4-6
4-2	Fugitive HC Monitoring Across the Finishing Stands Area of 84 Inch HSM, U.S. Steel, Gary Works	4-15
4-3	Summary of Hydrocarbon Analysis	4-25
4-4	Comparison of Stack Sample Analysis (Cold Mill) Versus Laboratory Simulation at 600°F	4-29
5-1	Inland Steel Company - East Chicago, Indiana	5-8
5-2	80 Inch 5-Stand Tandem Cold Reduction Mill Operating and Lubricant Parameters (Inland Steel - Indiana Harbor Works)	5-10
5-3	56 Inch 4-Stand Tandem Cold Reduction Mill Operating and Lubricant Parameters (Inland Steel - Indiana Harbor Works)	5-15
5-4	80 Inch 6 Finishing Stands Hot Strip Mill Operating and Lubricant Parameters (Inland Steel - Indiana Harbor Works, East Chicago)	5-19
5-5	United States Steel Corporation - Gary, Indiana	5-23
5-6	80 Inch 5-Stand Cold Reduction Mill Operating and Lubricant Parameters (U.S. Steel - Gary Works)	5-29
5-7	84 Inch (7 Finishing Stands) Hot Strip Mill Operating and Lubricant Parameters (U.S. Steel - Gary Works)	5-30
5-8	84 Inch (7 Finishing Stands) Hot Strip Mill Operating and Lubricant Parameters (U.S. Steel - Gary Works)	5-34
5-9	National Steel Corporation	5-39
5-10	80 Inch and 93 Inch Tandem Mills Cold Strip Reduction Area Operating and Lubricant Parameters (National Steel)	5-41
5-11	80 Inch (7 Finishing Stands) Hot Strip Mill Operating and Lubricant Parameters (National Steel)	5-46
5-12	Wheeling - Pittsburgh Steel Corporation	5-50
5-13	80 Inch (6 Finishing Stands) Hot Strip Mill Operating and Lubricant Parameters (Wheeling - Pittsburgh Steel)	5-52

LIST OF TABLES (CONTINUED)

Table		Page
6-1	Continuous Hot Roll Mills Over 1 x 10^6 Net Ton/Yr . . .	6-2
6-2	Cold Reduction Mills Over 0.9 x 10^6 Net Tons/Yr	6-4
6-3	Consumption of Rolling Oil, Lubricating Oil, Hydraulic Fluid or Grease in kg/MT (lb/ton) Steel Product for Cold Strip Mill in Different Steel Producing Facilities	6-7
6-4	Percentage Distribution of Total Lubricant (Oil, Hydraulic Fluid, Grease, and Rolling Oil Together) Consumption Through Various Loss Terms in Different Cold Strip Reduction Mills	6-9
6-5	Typical Cold Strip Tandem Mill Operating and Lubricant Parameters	6-11
6-6	Consumption of Rolling Oil, Lubricating Oil, Hydraulic Fluid, or Grease in kg/MT (lb/ton) Steel Product for Hot Strip Mill in Different Steel Producting Facilities	6-13
6-7	Percentage Distribution of Total Lubricant (Oil, Hydraulic Fluid, Grease, and Rolling Oil Together) Consumption Through Various Loss Areas in Different Hot Strip Reduction Mills	6-15
6-8	Typical Hot Strip Mill Operating and Lubricant Parameters	6-17
6-9	Typical Hot Strip Mill Operating and Lubricant Parameters	6-19
7-1	Typical Cold Mill Emission Results	7-2
7-2	Typical Hot Strip Mill Emission Results	7-3
7-3	Typical Plant Rolling Mill Emission Results	7-4

CONVERSION FACTORS

Much of the data collected during the performance of this study were reported in English units. Where possible, System International (SI) units of measure were used in the test of this report. When deemed impractical to convert data tables to SI units, a conversion factor is indicated. Following are the factors for conversion between English and SI units of measure.

1 lb (pound)	= 0.4536 kg (kilogram)
1 ton (short ton)	= 0.9072 metric ton (907.2 kg)
1 ft (foot)	= 0.3048 m (meter)
1 in (inch)	= 2.54 cm (centimeters)
1 gal (gallon)	= 3.7853 l or 0.0037853 m^3
1 MGD (million gallons per day)	= 0.0438 m^3/s (cubic meters per second)
1 GPM (gallon per minute)	= 6.309×10^{-5} m^3/s (cubic meters per second)
1 psi (pound per square inch)	= 6,895 pa (Pascal)
1 lb/ton	= 0.5 kg/1000 kg
1 gal/ton	= 4.172 l/1000 kg
^oF	= $1.8^oC + 32$

1.0 INTRODUCTION

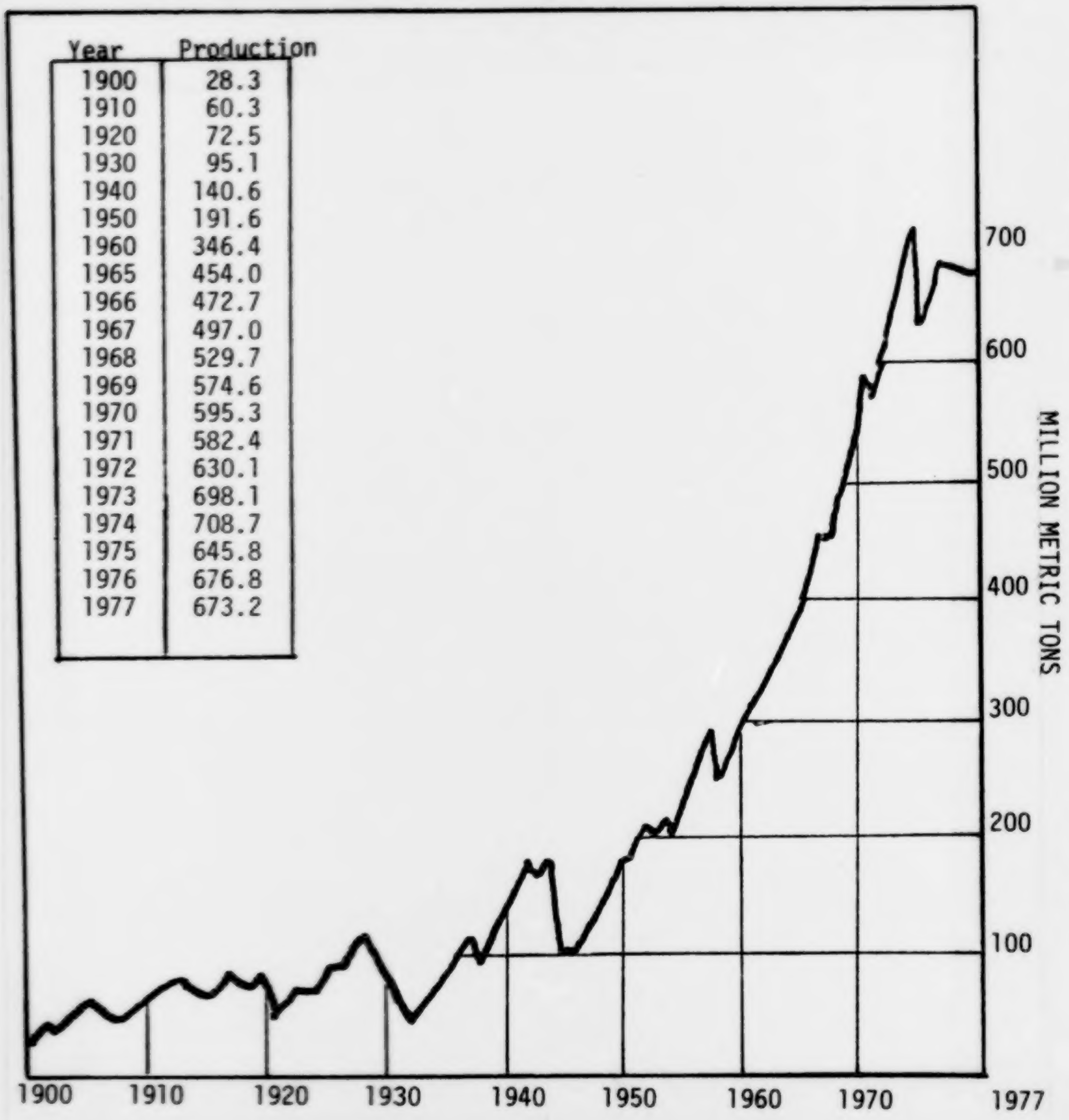
Steel production is one of the largest industries in the world. Thirty major steel producing countries (representing 97.6 percent of the world's steel production) produced 657.1 million metric ton (744.2 million ton) of steel in 1977. The United States produced 113.1 million metric ton (124.7 million ton) second only to the USSR's 145 million metric ton (159.8 million ton). The 1977 U.S. production level was about 83 percent of the annual capacity, and represented about 16.8 percent of the total world steel production. As can be seen in Figure 1-1, world crude steel production steadily increased until 1974 but has shown a slight downtrend in total production for the last four years.

Approximately 80 percent of all steel produced is processed through a hot sheet mill. The remaining portion of steel is directed to a variety of other mills including bar, billet, blooming, plate and rail. Hot sheet product is usually further processed by a series of cold mills which smooth and reduce the sheet to its final thickness, width and surface quality.

In a previous study, The Use and Fate of Lubricants, Oils, Greases, and Hydraulic Fluids in the Iron and Steel Industry, EPA 600/2-78-101, May 1978, it was determined that a typical integrated steel facility may emit, as air pollution, ten percent of the total quantity of oil, grease, and hydraulic fluid used. That study further demonstrated that 80 to 90 percent of the total oil, grease, and hydraulic fluid utilized by an integrated mill were consumed by the steel rolling and finishing operations (See Figure 1-2).

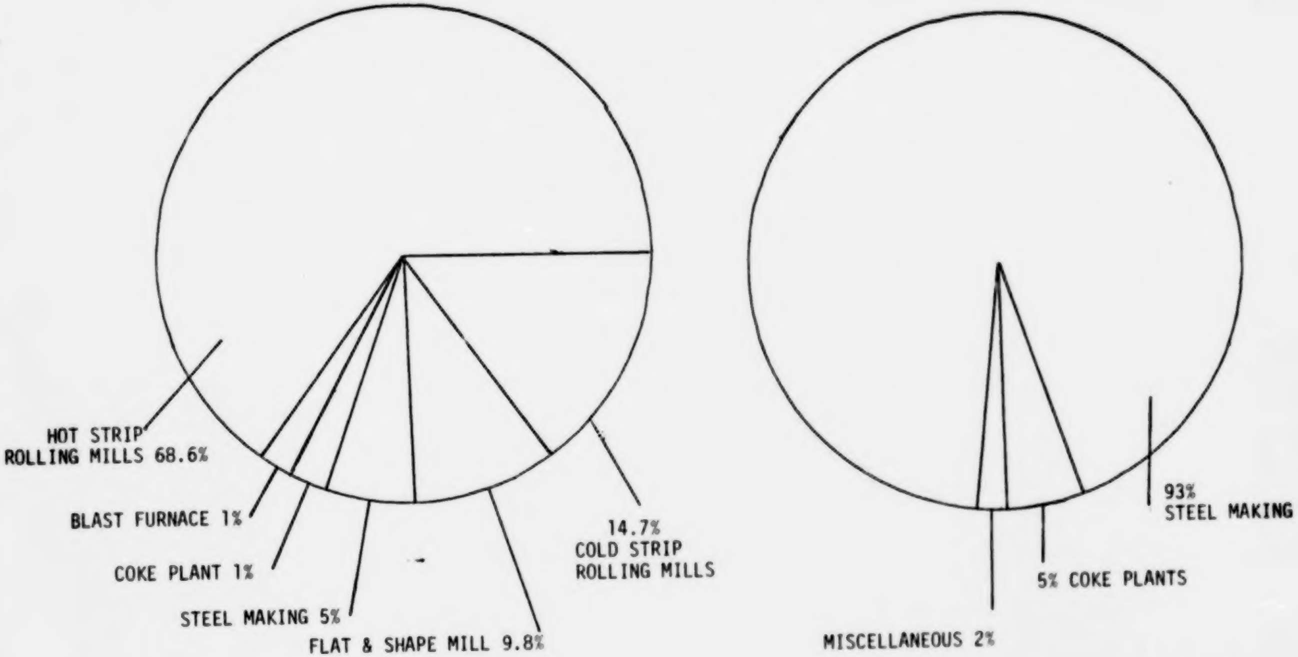
The use of lubricants, oils, greases, and hydraulic fluids in the iron and steel industry is a potentially significant source of pollution due to the large quantities that are used, and the numerous

Figure 1-1. WORLD CRUDE STEEL PRODUCTION



Year	Production
1900	28.3
1910	60.3
1920	72.5
1930	95.1
1940	140.6
1950	191.6
1960	346.4
1965	454.0
1966	472.7
1967	497.0
1968	529.7
1969	574.6
1970	595.3
1971	582.4
1972	630.1
1973	698.1
1974	708.7
1975	645.8
1976	676.8
1977	673.2

Figure 1-2. PERCENTAGE CONSUMPTION OF VARIOUS LUBRICANTS



PERCENTAGE DISTRIBUTION IN CONSUMPTION OF ROLLING OILS & GREASES IN VARIOUS AREAS OF TYPICAL STEEL PRODUCING FACILITY

PERCENTAGE DISTRIBUTION IN CONSUMPTION OF HYDRAULIC FLUIDS IN VARIOUS AREAS OF TYPICAL STEEL PRODUCING FACILITY applications of these materials. Pacific Environmental Services, Inc. was contracted by the Environmental Protection Agency's Industrial Environmental Research Laboratory in Research Triangle Park, North Carolina, to investigate volatilized lubricant and hydraulic fluid emissions from the steel industry. As in the previously cited study, fuel oils, solvents, tars, pitch, transformer oils, wash oils and quench oils were excluded from the investigation. That previous investigation revealed the fact that the two major potential sources of volatilized oils, greases, and hydraulic fluids were the rolling/ finishing mills and sinter plants. Sinter plants have and are being considered by other EPA supported studies, and therefore, were not considered during this study.

The purpose of this study was to investigate volatilization of oils, greases, and hydraulic fluids during usage in the steel industry. A determination was made of the quantity and characteristics of the resultant hydrocarbon emissions. The main sources of volatilized oil hydrocarbon emissions were identified and described by equipment types and plant areas. Lubricating and operating practices affecting oil volatilization and hydrocarbon emissions were also investigated. The four major goals of this contract were: (1) to survey the steel industry and collect data to perform oil, lubricant and hydraulic fluid mass balances around individual mill operations; (2) sample representative mills to verify the volatilization quantities calculated from the initial mass balance; (3) identify the quantity of lubricant volatilized by specific mill processes and determine the resulting hydrocarbon species; and (4) develop a standard methodology to perform mass balances for typical mill processes from the data compiled from the previous three objectives. The project was divided into six tasks: (1) review literature concerning lubricant usage and volatilization; (2) survey and collect data from the iron and steel industry; (3) conduct plant visits to obtain data and inspect equipment or plant areas identified as major volatilized oil sources; (4) develop and conduct a sampling program at one or two steel plants; (5) experimentally simulate lubricant volatilization in the laboratory; and (6) prepare a report describing the data, and present and discuss study findings.

Task One was to conduct a comprehensive literature search utilizing the resources of several technical libraries, trade journals, texts, handbooks, technical papers and NTIS microfiche. Background information was collected on processes and equipment, lubrication practices and usage, and waste oil collection and reclamation. Organizations, societies and industries supported by, knowledgeable of, or composed of iron and steel personnel were contacted to obtain information useful for the study.

Task Two was conducted to obtain detailed and current data on steel mill lubrication in the rolling/finishing mill areas. Steel facilities were contacted by telephone and follow-up letters sent to determine their willingness to cooperate and contribute to the project. Also, since in-plant testing was to be performed, the willingness to permit a sampling program was determined. Manufacturers and distributors of oils, greases, and hydraulic fluids were contacted to obtain product literature and specifications.

Task Three proved to be the most time consuming and perhaps the most important. In an effort to obtain data from the steel industry, two steel mill questionnaires were developed. The first questionnaire was general in content and was directed to all rolling/finishing processes located within individual facilities. The initial questionnaire proved to be too broad for most steel facilities to complete accurately; therefore, a second questionnaire was compiled which was directed to specific mill operations. This second questionnaire proved to be more a helpful and informative data collection tool.

Data were received from five plants, and four plant visits were arranged. The purpose of these visits was to obtain data, inspect equipment identified as significant hydrocarbon emission sources of volatilized lubricants, and to discuss the proposed sampling program.

Task Four consisted of plant visitation. Each facility was visited by two engineers who spent one full day at each plant. Their purpose was to obtain data not included in the lubrication questionnaires. Equipment and plant areas, identified as major volatilized lubricant hydrocarbon emission sources, were visually inspected and evaluated as potential candidates for the in-plant sampling program.

Task Five was conducted at two steel mill facilities: the Gary Works of United States Steel, and the Inland Steel Indiana Harbor Works. Stack samples from two cold roll mills were obtained from the Inland Steel facility. Ambient (building) air samples were acquired from the 84 inch hot strip mill located at U.S. Steel's Gary Works. Rolling oil samples and wastewater samples were also gathered from each of the locations. A gas chromatographic analysis was performed on each of the air samples. Each wastewater sample was also analyzed to determine the amount of oil present in the water during the air sampling period.

Laboratory experiments of Task Six were performed under controlled conditions on a typical rolling oil to determine the quantity of lubricant volatilized and the resulting hydrocarbon species. The results of this laboratory simulation were compared to the in-plant sampling results and the material balance estimates of the volatilized oil loss.

The data gathered in Tasks One through Six were reviewed and used to estimate hydrocarbon emissions resulting from volatilized lubricants and hydraulic fluids. These estimates were applied to the specific steel plants included in the study, a "typical" steel plant, and the domestic steel industry as a whole. The types of hydrocarbons produced by those evaluated processes were identified and quantified wherever possible.

The findings and analyses performed are described in this report. A general description of (1) the steel rolling and finishing processes; and (2) the lubricants used in these system operations are presented in Section 2. Sections 3 and 5 present a detailed description of the methodology used for gathering information, and the data obtained by these methods. The data acquired from the sampling programs are presented in Section 4. Descriptions of each process and the results of the laboratory analysis are provided. The project findings are summarized in Sections 6 and 7. The project conclusions, as well as areas or problems requiring further study, are also identified in these sections. This report includes the references used during the course of this project, and appendices which provide other data used in the study.

For the purposes of this report, the term "steel mill" will refer only to rolling and finishing operations. Wherever references to an entire steel plant are necessary, the terms "steel plant" or "steel facility" will be used.

2.0 PROCESS AND EQUIPMENT DESCRIPTION

A general knowledge of the process and equipment utilized in the shaping, rolling, and finishing of steel is needed to understand and appreciate the quantities and varieties of oils, greases, and hydraulic fluids consumed by these operations. A brief general description of the equipment and practices involved in the rolling/finishing of steel is presented in this section. A more detailed description of these processes and their associated equipment is presented in The Making, Shaping and Treating of Steel, available from the United States Steel Corporation.

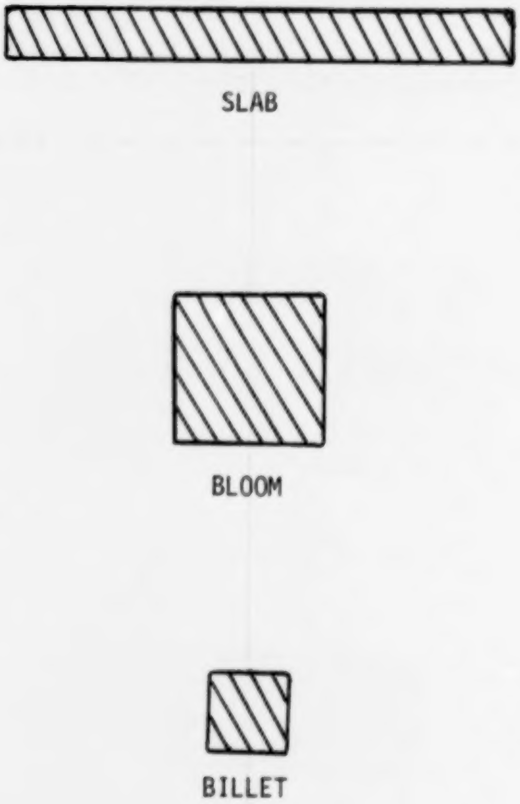
2.1 HOT ROLL PRODUCTION PROCESSES

The hot rolling of steel is the first step in the transformation of large steel ingots and slabs into usuable products. There are basically eight types of hot rolling mills: billet, blooming, slab, plate structural, bar, rail, and strip.

In the production of "blooms" which have square cross-sections, and "slabs," which have a rectangular cross-section, ingots are first heated in large soaking pits. These white hot ingots are transported to the blooming/slab mill where they are compressed by heavy rolls. The configuration of the rolls determines whether a slab or bloom is produced. In large steel facilities billets (same shape as a bloom but smaller cross-sectional area) are usually produced by taking rolled blooms directly from the blooming mill without reheating, cropping this bloom and then rolling the bloom in the billet mill (see Figure 2-1).

The most common form of blooming slab mills are the two-high reversing mill which consists of two rolls, one over the other. The reversing aspect of the mill refers to the change in direction in the mill after a piece of steel has made one pass. The number of passes

Figure 2-1. TYPICAL CROSS-SECTION OF SLAB, BLOOM, AND BILLET


SLAB
BLOOM
BILLET

per ingot is dependent on the amount of reduction needed. Other types of mills include three-high mills, two-high tandem mills, or a combination of any of these mills for special purposes.

In the three-high mill the rolls are not reversed; instead, the metal rests on tables that can be raised or lowered after each pass to the level between the two top rolls or the two bottom rolls. When finished, the bloom or slab, while still red hot, is carried on conveyor rolls to a shear and are cut to the desired length.

The two-high tandem mills utilize two or more two-high mills in a series. In this process the slab/bloom does not reverse direction and can be continuously produced (see Figure 2-2). Before further hot working, surface imperfections are removed by "scarfing" or burning-off with oxygen lances. After this operation the slabs are taken to a reheat furnace to bring them back to suitable rolling temperatures.

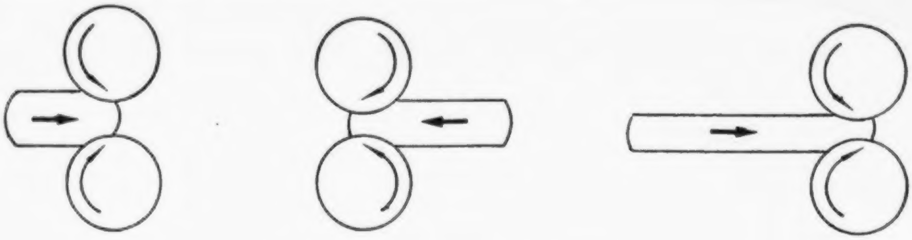
All of these mills are cooled and lubricated by flooding the work rolls with copious quantities of water.

Billets and slabs can also be produced by continuously casting molten steel into water cooled vibrating copper molds. This process is more economical than conventional rolling methods and seems to be the direction of new facilities.

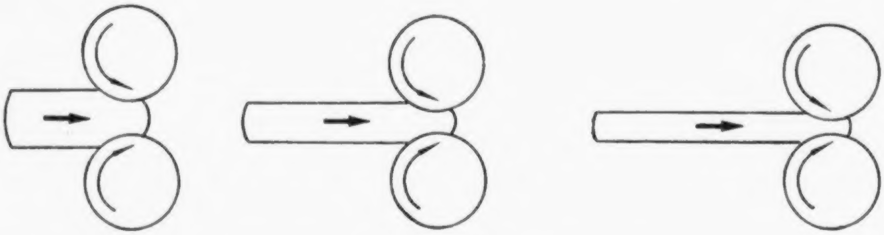
Plate, bar, rail, and hot strip mills further reduce the preprocessed slabs, blooms, and billets. Each mill has individual shaping equipment (called mill stands) which shape the hot steel into a variety of configurations such as railroad rails. Detailed discussions are not warranted as they are specialized adaptations of the same processes used in billet/slab mills.

The type of hot roll mill which was the focal point of this study was the hot strip mill. This mill processes slabs of varying thickness, widths and lengths; it produces strips/sheets in thickness ranging from 0.584 cm to 0.065 cm (0.230 to 0.026 inch). Table 2-1 presents the dimensional limitations for sheet and strip products.

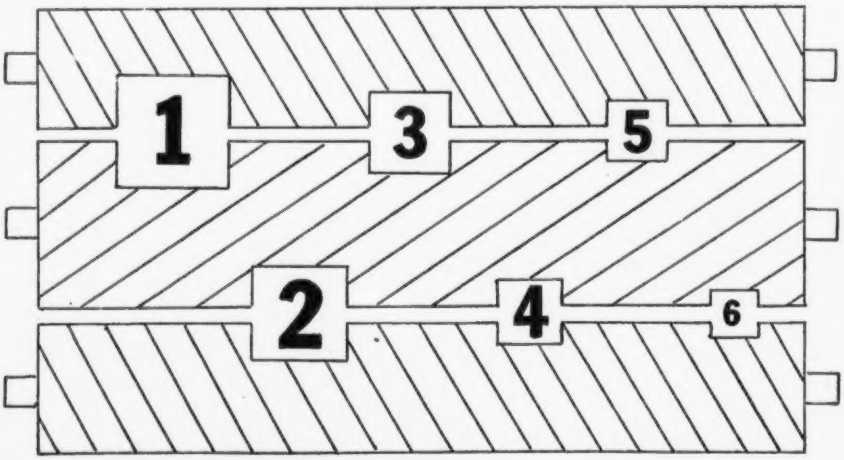
Figure 2-2. VARIOUS ROLLING MILL CONFIGURATIONS



TWO HIGH REVERSING MILL (3 PASSES)



TWO HIGH CONTINUOUS MILL (3 STANDS)



THREE HIGH BILLET MILL:
Numerals in pass openings indicate sequence of passes.

The temperatures on a continuous hot strip mill range between 1200°C (2200°F) (reheat furnace slab temperature), to 635°C (1200°F)(steel temperature in coiler). Each mill actually consists of several individual mills arranged in a straight line with a conveyor system connecting them.

The first major element in the hot strip rolling process is the heating of slabs to a rolling temperature of 1200°C (2200°F) in the reheat furnaces. The furnaces discharge the hot slabs at predetermined intervals on roller tables which direct the slabs to the first mills. In a typical hot strip mill, the first set of operations are usually performed in a combination of the following specialized mills: (1) vertical edgers which determine the final rolling width of the slab; (2) horizontal and finishing scale breakers which utilize large volumes of water, steam and/or air at high pressure to remove surface scale prior to final rolling; and (3) roughing stands which reduce the thickness of the slabs prior to entry into the finishing stands. Any or all of these primary mills may be combined in a single mill stand depending on the requirements of the facility.

The finishing stands reduce the steel to its final gauge and are the last reducing mechanisms on the mill. By the time the hot steel reaches the first-stand (of five to seven), the temperature has been reduced to 980°C (1800°F) by the cooling action of the water used on the previous mill stands. Each stand must be closely synchronized with the neighboring stands since strip speed increases from approximately 91.4 meter/min (300 ft/min) at the first stand to 1100 meter/min (3600 ft/min) at the final stand. The finished strip exits the final stand at a temperature of 704°C (1300°F), and proceeds to the run out table which incorporates water sprays and detention time to reduce the temperature of the strip to a final coiling temperature, below 650°C (1200°F). The coiler automatically grabs and winds the strips into coils which may have a weight in excess of 45,400 kgs (100,000 lbs).

Table 2-1. SHEET AND STRIP DIMENSION PARAMETERS

SHEET	
THICKNESS cm (inch)	WIDTH cm (inch)
0.584 cm (0.230 in) to 0.457 cm (0.180 in)	30.48 cm (12 in) to 121.92 cm (48 in)
0.456 cm (0.179 in) to 0.114 cm (0.0449 in)	Over 30.48 cm (12 in) to Over 121.92 cm (48 in)

STRIP	
THICKNESS cm (inch)	WIDTH cm (inch)
Up to 8.89 cm (3.5 in)	0.0648 cm (0.0255 in) to 0.5156 cm (0.2030 in)
Over 8.89 (3.5 in) to 15.24 cm (6 in)	0.0874 cm (0.0344 in) to 0.5156 cm (0.2030)
Over 15.24 (6 in) to 30.48 cm (12 in)	0.1140 (0.0449 in) to 0.58 39 cm (0.2299 in)

2.1.1 Equipment Utilizing Oil, Greases, or Hydraulic Fluids

All hot rolling process stages have one major element in common. Due to the number of moving parts, and the types of machinery, the lubrication requirements are immense. The high heat transferred from the hot ingots and strips, water exposure, and high scale/contaminant exposure requires that the lubricants used in these operations be designed to resist these adverse conditions. Each hot rolling operation has several lubrication points, including:

- mill table gears
- roll neck bearings
- spindle bearings
- screw downs, mill screws and nuts
- pinion stands and edger rolls
- roll changing ribs
- hydraulic accumulator
- roll balance systems
- general grease lubrication

Mill table bearings and gears are exposed to large quantities of water which may displace conventional lubricants and leave the machinery without protection. Whenever possible, most mills utilize a two step system to maintain lubricant protection in these areas. The first method is the use of heavier than water gear lubricants. These lubricants resist displacement by water and provide positive lubrication under large water exposure conditions. The second protection method is a lubricant recirculation system. Mills which utilize this system have large resevoirs connected in series with oil centrifuges for water removal, as well as oil sludge skimmers and magnets for metal removal. These recirculation systems are usually located under the equipment which they serve. In the case of a hot strip mill there may be as many as four separate recirculating systems, one each for the furnace roll table, primary (roughing) stands, finishing stand, and the coiler.

Roll neck bearings are prelubricated in the roll shop prior to their installation in the mill stands. Each time maintenance is performed on a working or back-up roll, the roll bearings are repacked with as much as 9 kgs (20 lbs) of new grease per roll side. Most other bearings on the mill stands are incorporated into the central lubrication system at that site.

The lubrication systems for screwdowns, mill screws, pinion stands, and edger rolls are all usually interconnected to a central recirculation system. All of this machinery utilizes EP (extreme pressure) gear oils of various grades to suit specific recirculation practices.

The roll balance system utilizes large quantities of hydraulic fluid. This hydraulic fluid may consist of water and oil mixtures (usually 90+ percent water, with ten percent oil used for corrosion protection) or pure mineral oil.

2.1.2 Use of Roll Oils

Rolling lubricants have long been an integral part of the cold rolling process, but are just beginning to gain acceptance in hot rolling applications. The use of high temperature rolling lubricants have many benefits:

- increased roll life
- decreased amount of roll grinding
- decreased total roll cost
- increased production
- decreased labor costs
- decreased pickling costs
- improved product.

The major problems associated with the application of rolling oils in the hot rolling process include:

- serious slippage (roll bite)
- inconsistent product coverage resulting in poor quality
- increased maintenance associated with lubrication system
- potential increase in pollution problem
- roll oil costs.

Until recently (post-1970), most attempts to incorporate rolling oils into hot roll production operations have failed to improve the process. Since the need to change rolls has always plagued hot mills, continued trials were conducted with roll oils in an effort to reduce downtime, improve overall mill performance, and lower mill costs. Developments in recent years have increased the use of rolling oils in various hot rolling operations, including hot-strip, structural and merchant mills. The roll oils used are similar to some of the oils used in cold rolling (see Section 2.1.2.2). For example, Sharon Steel of Farrell, Pennsylvania uses a rolling oil which has the following characteristics:

Free fatty acid as oleic	5.0 percent maximum
Flash point	460 °F
Fire point	520 °F
Pour point	32 °F
Viscosity SUS	
100 F	650
210 F	85
Viscosity index	120
Weight	7.64 lb per gal
Percent ash	less than 3.1 percent

The rolling lubricant has a high polar complexity, providing for good wetting on the hot mill roll surfaces. The oil has the ability to lay down a film which will remain on the surface of the rolls. The lubricant performs its function and then flashes off, eliminating any residue on the strip. The lubricant does not contain silicones, halogens, heavy metals, chlorinated solvents, acetone, benzene, etc., that would be detrimental or toxic. It is nontoxic even if ingested. The lubricant is synthesized and biodegradeable, and does not contain petroleum hydrocarbons or detergents.

Most hot roll oils carbonize to some extent when they come in contact with the hot strip which leaves a graphitic layer on the work rolls. The graphite residual maintains an even layer of lubricant on the rolls, thereby reducing excessive or uneven wear.

Rolling oil circulation systems have not been cost effective because the majority of roll oil either carbonizes, volatilizes, or combusts. Therefore, once-through (direct) application is the only application system presently being used. Due to more stringent regulations with respect to water discharges, this practice may change with the conversion of once-through water systems on hot strip mills to recirculation systems in the next five to ten years. It is estimated that approximately 50 percent of all hot strip mills in the U.S. presently use hot strip rolling oils, either on a regular or intermittent/experimental basis.

2.1.3 Wastewater Consideration

Water serves three purposes in hot rolling mills:

- cooling of roll trains, heating furnaces and ancillary equipment (motors)
- descaling of rolled products
- cooling of rolled products

Large volumes of wastewater are produced as a result of the use of water in the hot rolling operations.

Cooling water, used to cool internal sections of the mills, does not come in contact with the rolled steel, and contains if anything, only small amounts of oil due to leakage. This water can be recycled after cooling with a loss (underflow) of approximately one to five percent.

Cooling and descaling water when in contact with the rolled steel is contaminated by mill scale and oil. The size and quantity of mill scale depends on the size and type of mill. Most of the oil found in wastewater originates from roll trim lubrication.

For every metric ton of steel processed the water collects the following contaminants:

Oil	0.1 - 0.3 kg. (0.22-0.66 lbs)
Total Suspended Matter (TSM)	3 - 3.2 kg. (6.6-7.1 lbs)

The amount of oil discharged to a wastewater treatment facility from the hot strip mill studies averaged 0.125 kg oil per ton of steel produced.

In a typical wastewater treatment plant, the water would be treated by the following process:

- for sedimentation and flocculation, in a settling tank, a flocculating agent is added while a scraping arm traps oil
- addition of wastewater pickle liquor to reduce pH
- filtration through high rate sand filters
- removal of sludge by vacuum filters or centrifuges

All iron oxides and slurries recovered at the various stages of water treatment are removed by grate baskets, traveling cranes, or scraper chains and are returned to production either in the sintering plant or melting shop. The practice of charging hot strip scale to sintering plants is presently being discontinued due to the smoke and hydrocarbon pollution problems associated with the firing of oily scale.

Most steel plants incorporate wastewater treatment facilities which are designed to treat a number of varying wastewater streams at a central location. The benefits of this approach are: (1) lower capital and operating costs; and (2) positive pollutant removal effect which carefully monitored wastewater streams may have on each other (i.e. a waste pickle liquor stream added to a wastewater stream containing oil will reduce pH and enhance waste oil separation and collection). On the other hand, indiscriminate blending of waste streams may produce an undesirable pH range and lower concentrations of individual pollutants which can result in poor separation.

2.2 COLD ROLL PRODUCTION PROCESSES

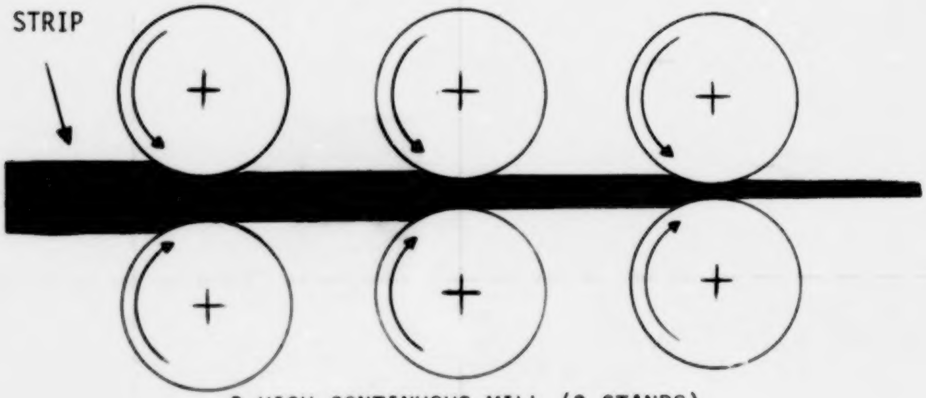
Further reduction in the thickness of hot rolled product is provided by cold rolling. In the cold roll process, steel can be reduced in thickness to a few thousandths of an inch. Other functions of the cold roll process are to improve surface quality, increase tensile and yield strengths, and increase hardness, which in turn decreases ductility. The principle cold finished flat-rolled products are flat bars, cold-rolled strip, cold-rolled sheets, and black plate (a product made of low carbon steel). In this report, the only cold-roll process to be discussed is cold-rolled carbon steel strip production. Prior to cold-rolling of strip, mill scale is removed from the hot-rolled strip usually by pickling process. In this process, the strip is passed through a warm dilute acid bath (sulfuric, hydrochloric, nitric or mixture) while with carefully controlling contact time to minimize any deteriorative effects on the steel itself. This treatment is followed by cold and hot water rinses, and subsequent drying.

Depending on the cold mills' production schedule, the cleaned strip may be coated with a thin layer of mineral oil to prevent rusting. This is usually done whenever long storage periods are expected.

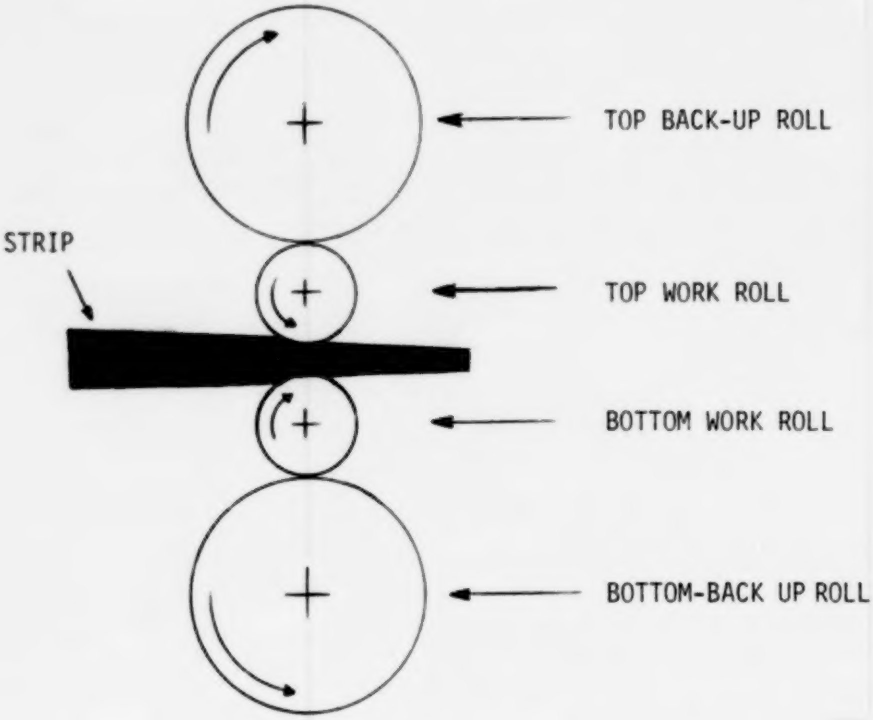
The pickled strip is then delivered to the cold mill in coils. As in hot rolling, a variety of mill stand arrangements are utilized. The bulk of the cold reduced flat steel made in this country is rolled on three- to six-stand four-high tandem mills. The other two common types of mills include four-high reversing mills and two-high cold mills (See Figure 2-3).

It is necessary to distinguish between the terms cold-rolling and cold reduction. Cold-rolling is a generic term applied to the process of passing unheated metal through heavy pressurized rolls to: (1) reduce thickness; (2) produce a smooth, dense surface; and (3) develop controlled mechanical properties. Presently, the industry uses the term cold-rolling to specify a rolling operation in which the thickness of the material is reduced slightly - usually just enough to impart a superior surface finish or adjust the mechanical properties of the steel. One such cold-rolling operation is referred to as "temper rolling" which reduces the thickness a minimum percent to obtain desired mechanical properties and surface characteristics.

Figure 2-3. TYPICAL COLD MILL ARRANGEMENTS



2 HIGH CONTINUOUS MILL (3 STANDS)

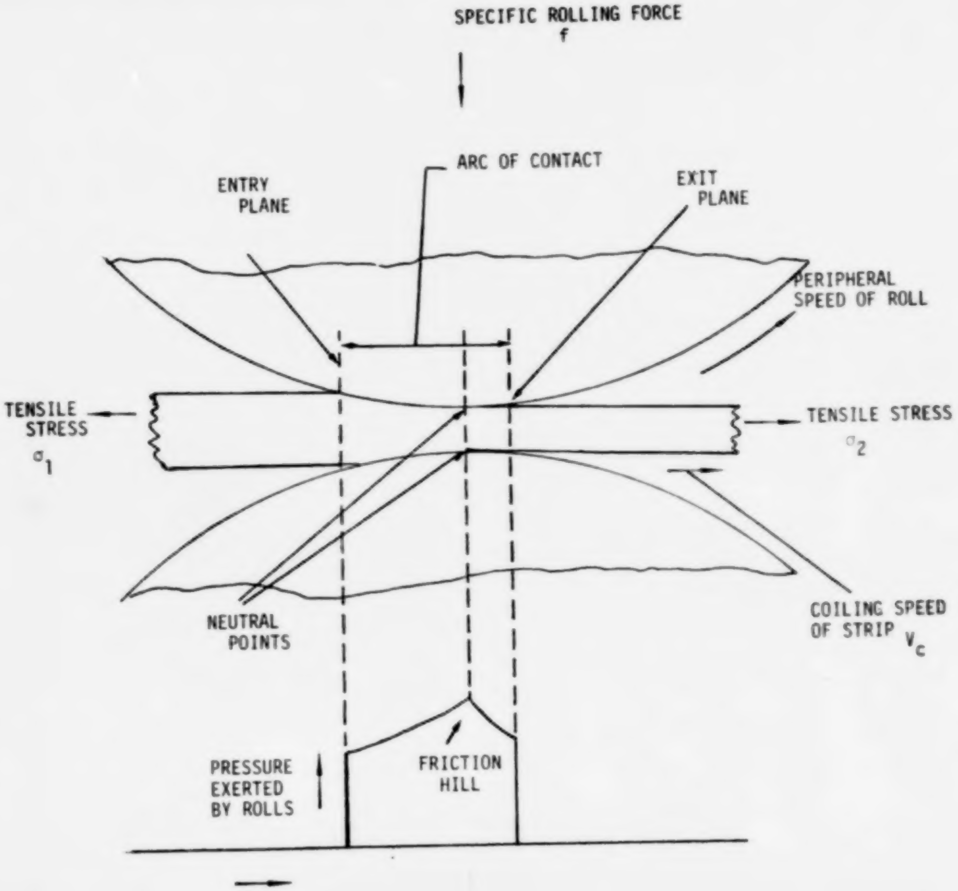

TOP BACK-UP ROLL
STRIP
TOP WORK ROLL
BOTTOM WORK ROLL
BOTTOM-BACK UP ROLL

Cold reduction is a particular form of the cold rolling process in which the thickness of the metal is reduced by relatively large amounts (i.e. 25 to 90 percent) in each pass through a single stand cold mill or in a series of passes through a tandem cold mill. As previously stated, the majority of cold reduction is performed by tandem rolling mills. The product is passed through three to six stands, each contributing to the thickness reduction and driving the material being rolled. This driving is usually synchronous so that the steel is in tension at all points on the mill. Unlike hot-rolling, no scale is formed, but much greater pressures and driving forces are required. To reduce the energy consumption in these mills, copious amounts of rolling oils are used to minimize the frictional forces inherent in the process.

Roll bite is a term used to define the ratio between the grabbing capability of the rolls versus the amount of slippage between the rolls and the steel strip. In the roll bite illustrated in Figure 2-4, slippage between the work roll and strip surfaces occurs along the length of each contact area. Only at the point designated as neutral are the roll and strip surface speeds identical; "true-rolling" (i.e. no friction) would occur at this point.

Friction is required to draw the steel strip into the roll bite, as all of the energy required to plastically deform the strip is transferred to the strip by frictional shearing forces. Excessive frictional forces are undesirable, since they must be balanced by an equal increase in energy consumption for high rolling forces and torques. Therefore, there is an optimum level of friction in the roll bite that balances the need to draw the strip through the rolls with minimum energy consumption. Rolling lubricants are used to achieve this optimum frictional level while maintaining a rolling force of sufficient magnitude to give acceptable shape and thickness to the rolled strip.

Figure 2-4. DIAGRAM OF THE ROLL BITE


SPECIFIC ROLLING FORCE
f
ARC OF CONTACT
ENTRY PLANE
EXIT PLANE
PERIPHERAL SPEED OF ROLL
TENSILE STRESS
σ_1
TENSILE STRESS
σ_2
NEUTRAL POINTS
COILING SPEED OF STRIP V_c
PRESSURE EXERTED BY ROLLS
FRICTION HILL

2.2.1 Equipment Utilizing Oil, Greases, or Hydraulic Fluids

Cold-roll reduction equipment utilizing oil, greases, or hydraulic fluids is very similar to that discussed in Section 2.1.1 for hot rolling mills. The major differences between hot and cold rolling lubrication needs are temperature and pressure. Cold mills do not encounter the high temperatures associated with hot rolling, but do impose much higher pressures to the strip, thus requiring high pressure greases and lubricants. As in hot rolling, each cold rolling operation has several common lubrication needs:

- mill table gears
- roll neck bearings
- spindle bearings
- screw down, mill screws, and nuts
- pinion stands
- roll changing rigs
- hydraulic accumulator
- roll balance systems
- general grease lubrication

Modern mills use centralized pressure lubrication systems to apply EP steel mill grease to the work roll bearings and table roll bearings. Although heat is not a major problem here, as in the hot mills, shock loads and washing effects of rolling fluids on the lubricant must be considered.

Back up roll neck bearings are primarily the oil film type, though many mills utilize roller bearings. The oil film bearings require a high quality mineral oil with excellent water separating properties. The use of properly selected rust and oxidation inhibiting oils can keep the oils in good condition over long periods of use. The low speed roller bearing mills are grease lubricated, although some modern high speed roller bearing mills are mist lubricated. Mist oils are especially formulated to prevent rust, suppress the formation of spray mist, and resist the formation of sludge and sediment which might interfere with the proper operation of misting equipment, as well as provide the required lubrication.

2.2.2 Use of Roll Oils

Rolling lubricants have long been an integral part of the cold rolling process. During the cold rolling process, the steel is subjected to very heavy pressures which reduce it to the desired thickness. Heat is developed to 315°C (600°F), chiefly from internal friction created by metal deformation (see Figure 2-4). Roll oils have the following general functions:

1. Lubricate the rolls and steel strip as it passes through the rolls. This permits maximum reduction of the steel, minimizes scratching of the metal, reduced power consumption, and lessens roll wear to minimize roll changes and mill downtime.

2. Remove frictional heat and maintain roll shape.

3. Provide a smooth and bright finish.

Although rolling lubricants are sold commercially under a variety of brand names, their basic constitutents are selected from oils, fats, and waxes. Prior to World War II, palm oil was the most widely used rolling lubricant, but the shortage of palm oil which developed at that time spurred the search for substitute materials. This search led to the use of tallows and the large number of other organic materials presently in use today, many of which are superior to palm oil. Roll oils can be classified into two categories, i.e., water base and oil base lubricants.

No two rolling operations are exactly alike with respect to speed, roll pressure, types of steel being processed, or amount of reduction. Many mill operators feel that each set of conditions require a different roll oil formulation. For that reason, a wide variety of specific roll oils are used, including:

- palm oil
- palm oil mixed with water
- palm oil mixed with soluble oil and water emulsions
- palm oil blended with straight mineral oil
- mineral oils (viscosity 100 to 200 seconds SUS at 100°F)

- mineral oil (viscosity 100 to 200 seconds SUS at 100°F) blended with fat or other polar materials
- palm oil substitutes (usually consisting of hydrogenated fats) mixed mechanically with water and emulsifiers
- soluble oils emulsified with water
- special roll oils for Sendzimir mills

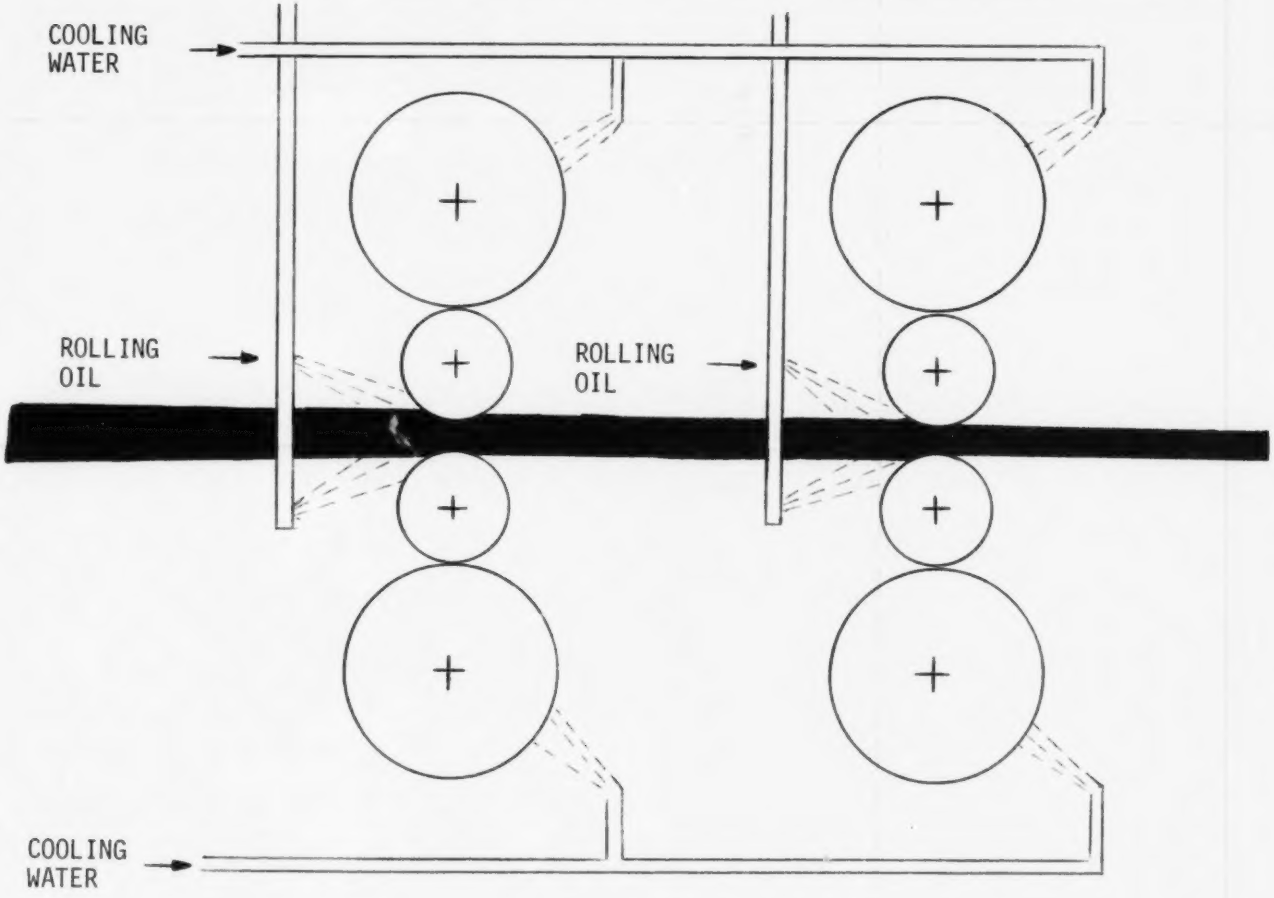
These lubricants contain organic compounds with carbon chain lengths in the range of C14 to C20. Some of these materials together with other pertinent information are listed in Appendix A, Table A-1. However, when sold as proprietary brands of rolling lubricants, they are usually blended with other materials such as emulsifiers, defoamers, antioxidants, and rust inhibitors.

Roll oils are applied by dripping, misting, flooding, or use of pads, etc., depending upon the specific application involved. Rolling lubrication systems may be categorized as either direct, wherein the lubricant is discarded after a single application; or recirculating, wherein the rolling solution is recycled from a large reservoir. As necessary, additions of lubricant are made to replace losses by evaporation, tank skimming, and residual lubricant left on the strip after rolling.

Direct application systems, illustrated in Figures 2-5 and 2-6, are presently being phased out due to wastewater pollution problems. Also, because of the single use of these lubricants, their consumption is high (2.1 to 2.9 kg/MT (5 to 7 lb/ton)), which increases mill operating expenses.

Recirculating systems are widely used on tandem cold mills. In the type of recirculation system illustrated in Figure 2-7, the effluent (usually between two to ten percent in concentration) is reused unchanged except for filtration, magnetic separation of iron fines, and intermittent skimming of the tanks. Quantities of new lubricant, equal to the initial amount of oil in the emulsion is added to the recirculation system every 10 to 20 hours of mill operation.

Figure 2-5. FOUR-HIGH TANDEM MILL WITH DIRECT APPLICATION OF ROLLING OIL


COOLING WATER
ROLLING OIL
ROLLING OIL
COOLING WATER

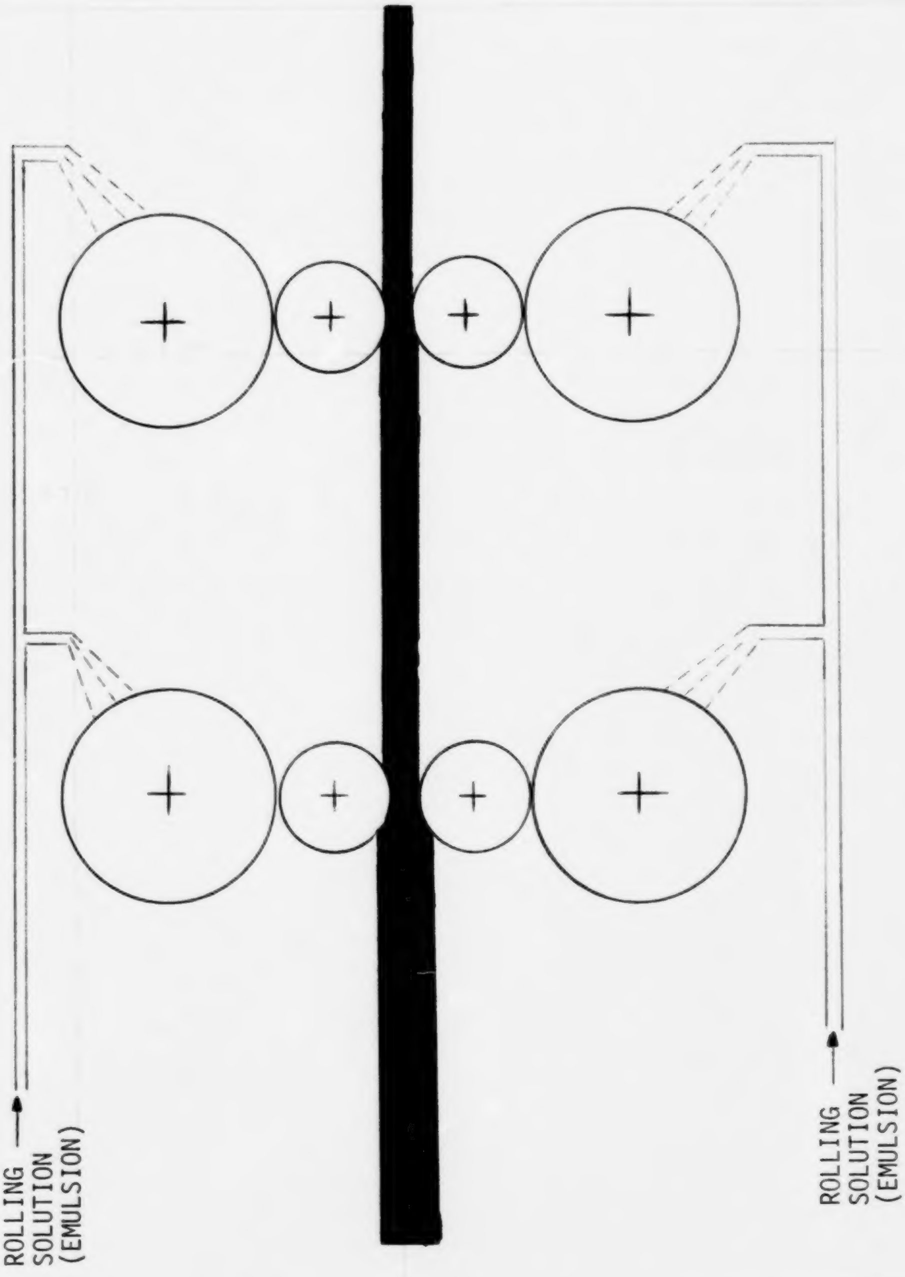
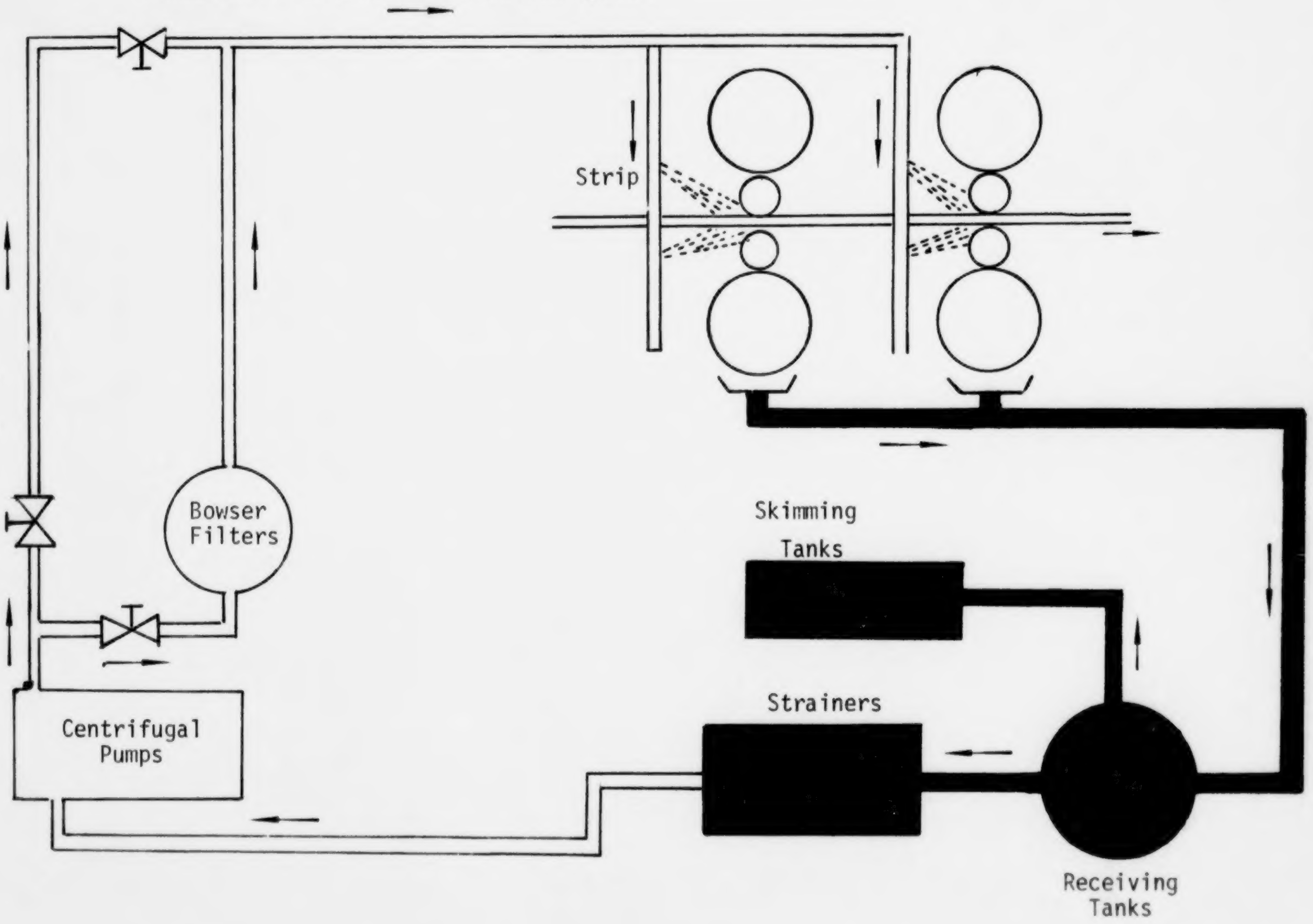

ROLLING SOLUTION (EMULSION)
ROLLING SOLUTION (EMULSION)

Figure 2-6. ROLLING OIL APPLIED AS AN EMULSION (FLOODING)

Figure 2-7. SCHEMATIC OF RECIRCULATING LUBRICATION SYSTEM

Tandem Mill Coolant Recirculation System


Strip
Bowser Filters
Skimming Tanks
Strainers
Centrifugal Pumps
Receiving Tanks

It must be reiterated that many mill operators feel that each set of mill conditions require different roll oil formulations and different quantities of oil for various products. No standard practices have been developed industry-wide, mostly due to the proprietary nature of the lubricant formulations and competition within the industry.

3.0 DATA COLLECTION

This section contains a description of the data gathering methodology. The problems encountered and measures necessary to overcome these problems are discussed.

3.1 QUESTIONNAIRE PREPARATION AND SURVEY DESIGN

To obtain sufficient data to identify and quantify lubricant and hydraulic fluid emissions from the industry, it was necessary to prepare a questionnaire and plan a survey of steel mills. During the initial literature review, the types of data needed and a project methodology were identified. Most of the data in the literature were not current and very little information was available related to lubricant usage, corresponding waste oil discharge rates, and recovery or disposal practices. Therefore, it was necessary to plan and conduct an expanded version of the iron and steel mill survey previously prepared by PES.

A copy of the initial "Iron and Steel Mill Lubrication Questionnaire" is presented on the next page. A great deal of data and information were requested, and a high degree of detail was solicited. The questionnaire dealt with two major areas: (1) lubricant and hydraulic fluid selection and use; and (2) waste oil recovery, wastewater treatment and discharge rates. It was expected that both lubrication and environmental personnel would respond to the questionnaire. By inclusion of nine mills in the survey, it was expected that adequate data could be compiled, even if specific mills did not respond to every question.

By definition, the project was to investigate rolling operations within integrated steel mills. The emphasis was placed on larger rolling steel mills, as they would be more likely to have extensive environmental and lubrication departments, and therefore more extensive data and records relevant to the study.

PACIFIC ENVIRONMENTAL SERVICES, INC.

Iron and Steel Mill Lubrication Questionnaire*

Plant Identification: ________

1. How many of the following types of mills are currently in operation?

	No.
Slab	________
Blooming	________
Billet	________
Rod and Bar	________
Rail Hot Strip	________
Tin Cold Reducing	________
Tin Cold Finish - Temper	________
Sheet - Cold Reducing	________
Sheet - Cold Finish Temper	________
Other	________

2. List all lubricants, oils, greases, and hydraulic fluids used by these processes. Please specify where the lubricants are used, and in what quantity.

3. Are any of the above lubricants recovered/reclaimed? If so, which ones and in what quantities are they recovered/reclaimed?

4. Are any of the above lubricants recycled? If so, which ones and in what quantities are they recycled?

5. Who are the major suppliers of the lubricants used?

6. How much oil is recovered from wastewater treatment facilities serving these processes? What are the collection efficiencies of these units?

---

* Under EPA Contract No. 68-02-2606
June, 1978

The nine steel mills were selected based on the basis of participation during the previous study (EPA-600/2-78-101).

3.2 CONTACTS AND RESPONSES

The process of obtaining data began with the identification of key personnel at each steel mill. Telephone calls were made to the director or department head of the environmental control section. PES and the EPA contract were introduced and a brief description was provided of the nature of the study and types of data being sought. The name, title, address and telephone number of the steel mill personnel who would prepare the responses were noted.

Questionnaires with cover letters were mailed to the nine steel mills during May and June of 1978. After approximately one month, follow-up telephone calls were made to determine the expected completion date and resolve any questions which may have arisen. Several factors caused significant delay in questionnaire completion. Some of those reasons cited were: need to approve data requests with higher corporate authorities; need to coordinate and gather substantial amounts of data; and difficulty in justifying man-hour allocations for this type of activity. There was also some reluctance to provide data to an EPA contractor. This was attributed to industry fear that it could be detrimental to their interests. PES attempted to counter this by stressing the research role of IERL.

By August only two mills had submitted usable data. The remaining mills stated that the information requested was not available. To minimize data requests, PES developed a second lubrication questionnaire specific to individual rolling mill operations entitled, "Steel Mill Checklist" (See following page). This questionnaire was sent to the initial list of mills. Five steel facilities completed the second questionnaire.

STEEL MILL CHECKLIST

Interviewer's ______________________ Date __________

Facility Name ______________________

Mailing Address ______________________

Persons Interviewed	Name	Position/Title
	____________	____________
	____________	____________
	____________	____________

Data Age (Year) ______________________

1. Lubricant Purchases	All Rolling Mills	For 80" Hot Strip
a. Oils (gal/yr)	____________	____________
b. Greases (gal/yr)	____________	____________
c. Hydraulic Fluids (gal/yr)	____________	____________
2. Lubricants used (types and quantities)(gal/yr)	____________	____________
	____________	____________
	____________	____________
	____________	____________
	____________	____________
3. Types of Rolling oils used and quantities	____________	____________
	____________	____________
	____________	____________
	____________	____________
	____________	____________

	All Rolling Mills	For 80" Hot Strip
a. Are rolling oils recycled?		
b. What is underflow rate?		
c. Storage capacity of System (gal)		
4. Oil Recovery System used?		
2. Methods of Disposal for Unrecovered Oil		
6. Quantity of mill scale		
a. Quantity of scale returned to sinter plant?		
b. to blast furnace?		
7. Quantity of mill sludge		
a. Where is sludge disposed?		
b. Is sludge recycled?		
c. What method?		

Participating steel mill personnel estimated three to four months would be required to collect the desired information. It was decided to recontact each of the mills periodically (once or twice per month) to ensure that the questionnaire had not been forgotten and to answer any questions. The importance of current industry data required continued contact with the steel mills. Project schedules were modified to reflect the delays.

3.3 PLANT VISITS AND INTERVIEWS

The initial questionnaire responses generally lacked the degree of detail desired, particularly for developing material balance estimates of oils, greases, and hydraulic fluids. It was decided that an attempt would be made to visit each of the participating steel mills to inspect facilities and interview personnel knowledgeable on lubricant use and application, waste oil recovery, reclamation, and wastewater treatment. Telephone calls were made to the steel mills and followed by written requests for a plant visit.

Permission and arrangements to visit and discuss the project objectives and methodology were finalized for four of the five steel mills who responded to the questionnaires. One-day plant visits and appointments with environmental and lubrication department personnel were scheduled from August to December 1978 for the following plants:

- United States Steel Corporation - Gary, Indiana
- Inland Steel Company - East Chicago, Illinois
- National Steel - Detroit, Michigan
- Florida Steel - Charlotte, North Carolina

The data provided in the initial written responses were discussed at the plant visits, and the steel making and shaping equipment, waste oil recovery practices, and wastewater treatment facilities were inspected. The scope and objectives of the project were reviewed and data availability discussed. If additional useful data was determined to be available, a request for such data was made. Also, during these visits the plants were surveyed for the sampling program portion of the project. It was decided that the rolling mills located within the Inland Steel Indiana Harbor Works and the United States Steel Gary Works were preferred for the sampling program.

3.4 SAMPLING PROGRAM

During the facility visits to the Indiana Harbor and Gary Works, formal requests for permission to conduct a sampling program were made. Permission was requested from Inland Steel to sample hydrocarbon emissions from their 80 inch hot strip mill, 80 inch tandem mill, and the 56 inch tandem mill. A discussion of the proposed sampling program, methods, and equipment was held. It was determined that actual sampling would be performed on the two (80 inch and 56 inch) cold tandem mills. However, due to safety considerations and crane availability, sampling at the 80 inch hot strip mill proved to be infeasible. Since Inland agreed to allow their two cold mills to be sampled, U.S. Steel was asked for permission to sample their 84 inch hot strip mill. This mill was deemed the most ideal of the hot strip mills surveyed, since it utilized rolling oils.

Sampling of Inlands' cold strip mills took place on the week of December 17, 1978. Three days were required to set up the sampling equipment, perform the sampling program, and disassemble the sampling train. Inland Steels' maintenance personnel were very cooperative and supplied access ports on the two stacks to be tested.

The United States Steel 84 inch hot strip mill was initially scheduled to be sampled in early January of 1979. Severe winter weather delayed the program until March 1979. At all times, mill personnel stressed the safety considerations involved in such a sampling task (see Section 4.2). After numerous discussions with mill personnel, it was decided to perform testing only at the 84 inch hot strip mill finishing stands.

Three separate types of samples were gathered at each mill site:

- continuous hydrocarbon sampling
- wastewater and rolling oil samples
- air grab samples

Grab samples were collected for gas chromotograph and infrared spectograph analysis. A mass balance analysis of each mill was then conducted utilizing information gathered during the sampling program, and from previous telephone conversations and plant visits. To supplement the steel mill data, a laboratory simulation was conducted to quantify the volume and type of hydrocarbon species generated by the rolling operations. The laboratory simulation is discussed in Chapter 4.

4.0 HYDROCARBON SAMPLING AND ANALYSIS

In an effort to collect actual field data, emission sampling was performed on two cold mill facilities and one continuous hot strip operation. Of the mills which participated in the questionnaire portion of this study, Inland Steel Indiana Harbor Works, and United States Steel Gary Works agreed to emission sampling programs. The sampling program and analysis are described in this chapter.

4.1 INLAND STEEL INDIANA HARBOR WORKS

Inland Steel, Indiana Harbor Works, East Chicago, was contacted in late November 1978 concerning performance of stack sampling on a continuous basis for determining hydrocarbon emissions from their steel rolling operations. During this visit it was determined that the two most suitable mills for the sampling program were the 56 inch four-stand tandem mill and the 80 inch five-stand tandem mill. Both of these mills had central air evacuation systems which exhausted to a central stack. The 80 inch hot strip mill was also considered for the sampling program, but due to safety considerations and crane availability, sampling at this mill proved to be infeasible. The stack sampling program for total hydrocarbon emissions was conducted during late December, 1978.

The air evacuation system for each of these mills collect volatilized hydrocarbons and water vapor from rolling operations and exhausts the gas into a vertical circular stack. The evacuation system is necessary because large amounts of water and oil would otherwise condense on the rolling train. Also, cold mill operators must work very near the rolling train, and the evacuation system insures that oil or water will not hinder the operators' ability to perform their assignments. A fog/mist eliminator is located in an underground exhaust tunnel to aid in the elimination of any aerosols that may reach the system's induction (I.D.) fans. By visual emission (opacity) observations, the capture efficiency of the evacuation system was estimated by PES to be 95 percent with the remaining five percent escaping to the mill building atmosphere. For calculation purposes, it was assumed that all of the non-captured vapors/aerosols condensed within the building. They were considered as part of the leak, spill, and trash components of the mill mass balance.

A schematic diagram of the 80 inch five-stand tandem mill air evacuation system and the position of the stack sampling probe is presented in Figure 4-1. Both the 56 inch and the 80 inch tandem mills have closed rolling solution systems to provide a continuously recirculated oil/water solution to the mill stands. Volatilized vapors and aerosols are directed to the evacuation system.

4.1.1 SAMPLING TRAIN

The sampling train used to conduct stack hydrocarbon emissions sampling is presented in Figure 4-2. Since there presently is not an approved EPA sampling method for the quantification of total hydrocarbon emissions, PES developed this sampling train. The train consists of a probe, four impingers, one fiberglass thimble, a diaphragm pump connected to a dry gas meter, and a Beckman model 400 analyzer. The analyzer was connected to the train by means of a bypass tee which diverted a portion of the mill vapor to the instrument.

4.1.2 SAMPLING AND DATA COLLECTION

The sampling site was approximately 7.6 meters (25 ft) above ground floor level to ensure minimum flow disturbances within the stack. The sampling train was assembled on a platform next to the stack. Inland Steel personnel provided access ports for each of the stacks. Sampling on these stacks had never previously been conducted. The hydrocarbon emissions were continuously measured by a Beckman Model 400 Hydrocarbon Analyzer, a flame ionization detection

Figure 4-1. FIVE-STAND TANDEM COLD STRIP MILL AIR EVACUATION SYSTEM (80 Inch Mill)

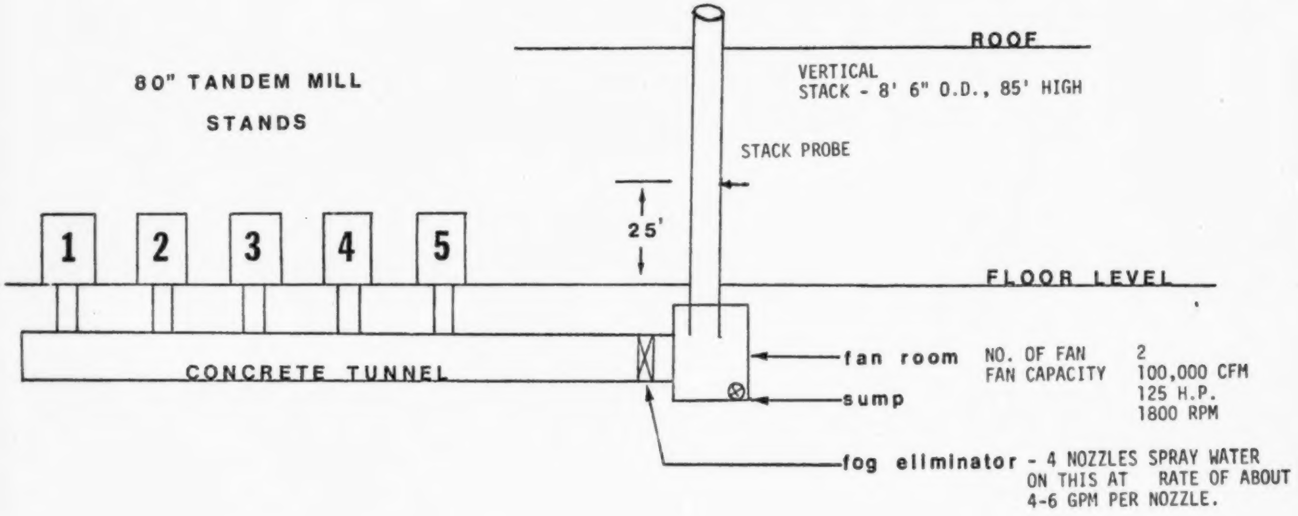
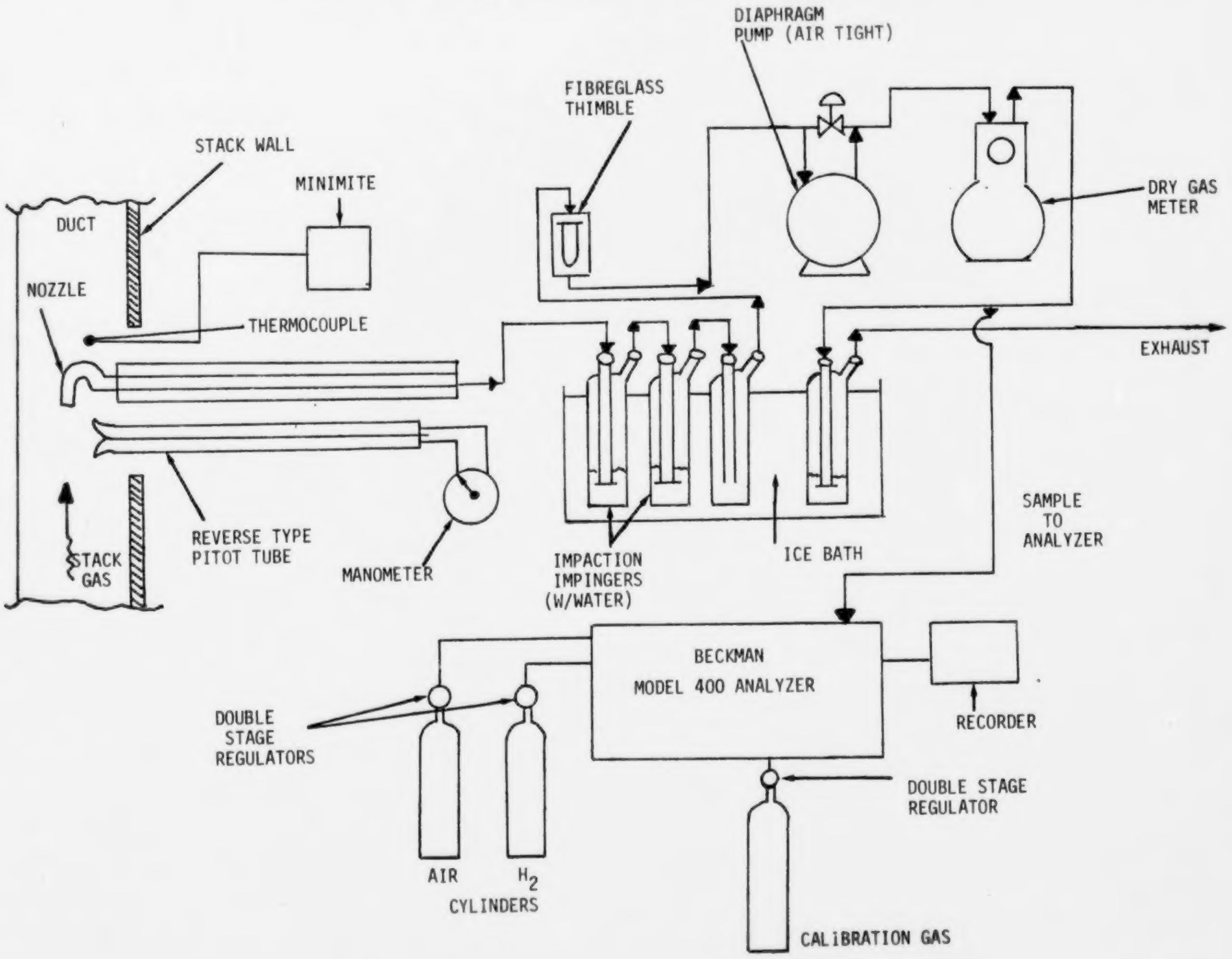

80" TANDEM MILL STANDS
1
2
3
4
5
CONCRETE TUNNEL
ROOF
VERTICAL STACK - 8' 6" O.D., 85' HIGH
STACK PROBE
25'
FLOOR LEVEL
fan room
sump
NO. OF FAN 2
FAN CAPACITY 100,000 CFM
125 H.P.
1800 RPM
fog eliminator - 4 NOZZLES SPRAY WATER ON THIS AT RATE OF ABOUT 4-6 GPM PER NOZZLE.

Figure 4-2. STACK SAMPLING TRAIN AND HC ANALYZER


DIAPHRAGM
PUMP (AIR TIGHT)
FIBREGLASS
THIMBLE
STACK WALL
MINIMITE
DRY GAS
METER
DUCT
NOZZLE
THERMOCOUPLE
EXHAUST
STACK
GAS
REVERSE TYPE
PITOT TUBE
MANOMETER
IMPACTION
IMPINGERS
(W/WATER)
ICE BATH
SAMPLE
TO
ANALYZER
BECKMAN
MODEL 400 ANALYZER
RECORDER
DOUBLE
STAGE
REGULATORS
DOUBLE STAGE
REGULATOR
AIR
H2
CYLINDERS
CALIBRATION GAS

unit that measures total hydrocarbons (expressed as methane). Water was placed in the first, second, and fourth impingers of the train to trap any condensible hydrocarbons.

Continuous HC stack sampling was conducted and measured on the HC analyzer for approximately 90 minutes in each of the 56 inch and 80 inch tandem mill exhaust stacks. The readings were taken every ten minutes and recorded. The 56 inch tandem mill had been down for maintenance for two days prior to the test. The sampling was initiated approximately 10 to 15 minutes after the mill start-up. In the case of the 80 inch cold tandem mill, testing was performed after the mill had been in operation on a semi-continuous basis for four days. Approximately 15 minutes into the sampling program, the 80 inch mill stopped all production for a roll change. This condition lasted for approximately 15 minutes and the mill resumed normal operation after the roll change.

4.1.3 DATA ANALYSIS

Data were recorded on the source test data forms during the hydrocarbon stack sampling test runs. These data were further analyzed for total hydrocarbon emissions. A summary of the test analysis is provided in Table 4-1. Moisture content, stack gas velocity, volumetric flow rate, average hydrocarbon concentration, and total hydrocarbon emissions analysis are presented in detail in Appendix B, Sections B-1, B-2, B-3, and B-4.

The average total HC concentration for each mill (from calibration curves) was found to be:

Cold Strip Mill	Total Hydrocarbons (as methane) (Actual concentration, ppm) Averaged over test period
56 inch 4-stand	59
80 inch 5-stand	57

Table 4-1. STACK TEST DATA ANALYSIS SUMMARY*

PARAMETER	56" 4-Stand	80" 5-Stand
Moisture content: (EPA Method 4)	15.2%	18.1%
Stack Gas Velocity: (SCAQMD)	27.84 ft/sec	31.05 ft/sec
Volumetric Flow Rate:	93,960 CFM	104,718 CFM
Avg. HC Concentration:	59 ppm	57 ppm
Total Hydrocarbon Emissions:	60 tons/yr	62 tons/yr
Stack Diameter:	8'-6"	8'-6"
Probe Nozzle Diameter:	0.25"	0.25"

* Refer to Appendix B for calculation details

4.1.3.1 Hydrocarbon Emissions

During the sampling, the concentration of total hydrocarbons (as methane) measured on the Analyzer ranged from 56 ppm to 63 ppm for the 56 inch Tandem mill, and from 54 ppm to 58 ppm for the 80 inch Tandem mill. The HC concentration variation with time for both the 56 inch mill and the 80 inch mill is shown in Figure B-1 and Figure B-2, respectively, Appendix B. Samples were continuously monitored and were recorded on an accompanying strip chart. Also recorded at this time were pump vacuum, impinger temperature, stack temperature, sampling rate and pressure drop across the pitot tube (See Tables B-1 and B-2 in Appendix B).

The total hydrocarbon concentration (as methane) in ppm was averaged over the entire sampling period and the actual value of this average concentration was then derived from the calibrations (see B-4, B-5, B-6 in Appendix B for calculation details). The experimental set-up for calibrating the analyzer is shown in Figure B-3 (Appendix B).

4.1.4 GRAB SAMPLES

Grab samples were taken from each of the 56 inch tandem and the 80 inch tandem mill exhaust stacks during the period when continuous stack hydrocarbon sampling was conducted with the sampling train and the Model 400 HC Analyzer.

The Standard Recommended Practice for "Sampling Atmospheres for Analysis of Gases and Vapors" issued under the fixed designation C 1065-60 (Reapproved 1973) by American Society for Testing and Materials (ASTM) references the sampling method - Sampling Atmospheres With Concentrations of Gases and Vapors - was specifically followed during the grab sampling. The grab samples (from the 56 inch mill and the 80 inch mill) collected by this method were analyzed for chemical composition/hydrocarbon species at a remote laboratory.

Gas sample tubes (Type B) as shown in Figure 4-3 were used. Sample tubes had a capacity of 250 c.c., and were made from glass. The tube had airtight stopcocks at each end. Any aspirating device, such as a vacuum pump, can be used to evacuate the tube.

The arrangement for evacuating the tube is shown in Figure 4-3. When the sample tube is evacuated, the stopcock near the vacuum pump remains in the open condition. Both stopcocks are greased to assure a leak proof seal. The original gas content was evacuated to a gauge condition of 27 inch Hg vacuum. To collect the grab sample, the evacuated tube was connected to the sampling train and filled with the stack air. The sampling was isokinetic, and hence, the grab sample was considered representative of the stack air. A representative sample of rolling oil (emulsion oil) utilized in the rolling operation was also collected during the period. The glassware associated with the sampling train at the end of the test runs was washed with water and acetone to collect any organic matter.

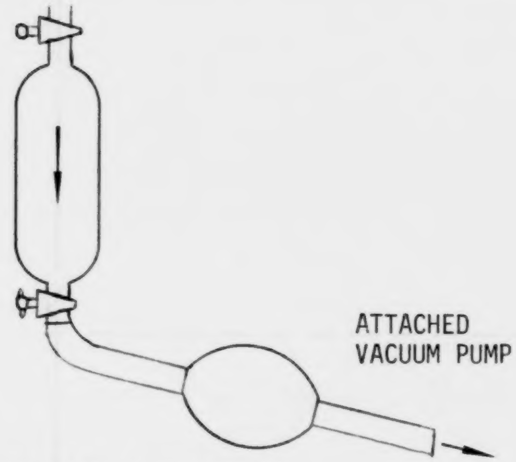
The grab samples from the 56 inch mill and 80 inch mill as well as water wash and acetone wash samples were collected, packed, and shipped to the laboratory for analysis within 24 hours of sampling to safeguard against any possible change in the particular constituents or properties of the collected samples.

4.1.5 LABORATORY ANALYSIS

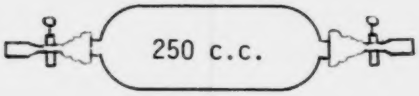
The oil emulsion, vapor grab samples, and the impinger water samples collected during the tests were analyzed for chemical composition/hydrocarbon species. The laboratory procedures for the analysis are outlined below.

Sample Preparation: Each sample was acidified with concentrated sulfuric acid upon collection. The water samples and emulsion samples were extracted with three 100 ml portions of pesticide grade chloroform. The extracts were dryed with anhydrous sodium sulfate and concentrated on a rotary evaporator. The total amount of oil recovered was then weighed.

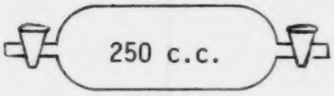
Figure 4-3. GAS SAMPLE TUBES FOR COLLECTION OF SAMPLE BY DISPLACEMENT


ATTACHED
VACUUM PUMP

GAS SAMPLE TUBE PLUS VACUUM PUMP



TYPE A



TYPE B

The acetone samples were concentrated with a rotary evaporator. The remaining oil and water was transferred to a 250 ml separatory funnel and extracted with two 50 ml portions of pesticide grade chloroform. The extracts were dryed over anhydrous sodium sulfate and concentrated to dryness. The total amount of oil recovered was then weighed.

The air sampling bulbs were washed with pesticide grade chloroform and the washings concentrated on the rotary evaporator. The total amount of oil was estimated as accurately as possible.

Column Chromatography Separation: Aliphatic and olefinic hydrocarbons were separated by column chromatography according to the procedure by Gearing, et.al. The aliphatic hydrocarbons were eluted from a 400 mm x 10 mm chromatographic column containing 12 grams of activity 1 silica gel and three grams of activity 1 neutral alumina with 60 mls of pesticide grade hexane. The olefinic hydrocarbons were eluted with 60 mls of pesticide grade benzene. The amount of oil recovered from the two fractions were totaled and the portion of the total not recovered was considered polar lipid materials.

Gas Liquid Chromatographic Analysis of Aliphatic Hydrocarbons: The aliphatic hydrocarbons, C-14 through C-38 were separated and quantitatively identified by gas-liquid chromatography. The separation was done on a 20 ft x 1/8 inch 30 percent Eutectic column in a Bendix 2700 GC equipped with a FID detector. The column temperature was programmed from 100 to 350°C at 10°C/minute with nitrogen carrier gas flow rate of 40 ml/min. The peaks were identified and quantified by comparing them with a standard hydrocarbon mixture prepared from Alltech Associates standards.

Infrared Analysis: Infrared spectra of the extracts from oil/water emulsions were run on a PE 337 infrared spectrometer. The spectra are included in the report. They are typical spectra for hydrocarbon oils.

Chemical Analysis Summary: Chemical analysis of the stack air grab samples and emulsion oil samples, as well as wash water and wash acetone indicated the presence of three types of hydrocarbons:

1. Aliphatic
2. Olefinic
3. Polar lipids

Aliphatic hydrocarbons are parafinic-type compounds.

Olefinic compounds are unsaturated hydrocarbons containing a double bond.

Polar lipid compounds are cyclic, aromatic in nature with single or double multiple rings.

Aliphatic hydrocarbon emissions were further identified to be in the range of C-14 through C-38 by gas and liquid chromatography. The majority of aliphatic hydrocarbons emitted from the 56 inch mill exit stack were in the C-16 to C-19 range (51.5 percent). The 80 inch mill aliphatic hydrocarbons were more evenly distributed through the C-14 to C-28 range with the C-16 through C-19 portion being 40.2 percent (See Tables B-3 through B-6 in Appendix B). This analysis indicates that the lubricants volatilized in these rolling operations are complex mixtures of long chain hydrocarbons (high molecular weights).

The grab samples of the emulsions used on the mills were also analyzed for hydrocarbon content to determine if any substantial chemical decomposition occurred during the rolling process. In both instances, the majority of aliphatic hydrocarbons were in the C-14 through C-16 range (58.8 percent at the 56 inch mill; 47.3 percent at the 80 inch mill), which is slightly less in length than those found in the stack grab samples (see Tables B-7 and B-8 in Appendix B).

No further anlysis of the olefinic and polar lipid hydrocarbon species were performed.

4.2 UNITED STATES STEEL GARY WORKS

United States Steel was contacted in November of 1978 concerning the sampling for hydrocarbon emissions from their steel rolling operations. During the visit to the facility, PES determined the most suitable mills for the sampling program were the five stand tandem tin mills and the 84 inch continuous hot strip mill. Since two cold mills at the Indiana Harbor Works had already previously been scheduled for sampling, only the 84 inch hot strip mill was chosen for sampling. The sampling program was initially scheduled to be conducted in late January but due to inclement weather the program was not performed until early March of 1979. Also due to the severe midwest winter, the rolling solution application system for the mill malfunctioned. Therefore, all hot strip sampling was performed while no rolling lubricant was in use. Therefore, this sampling serves as a baseline concerning continuous hot strip mills, since the only oil applied to the strip originates from two uncontrolled factors: (1) mill water oil content; and (2) mill machinery lubricant leakage.

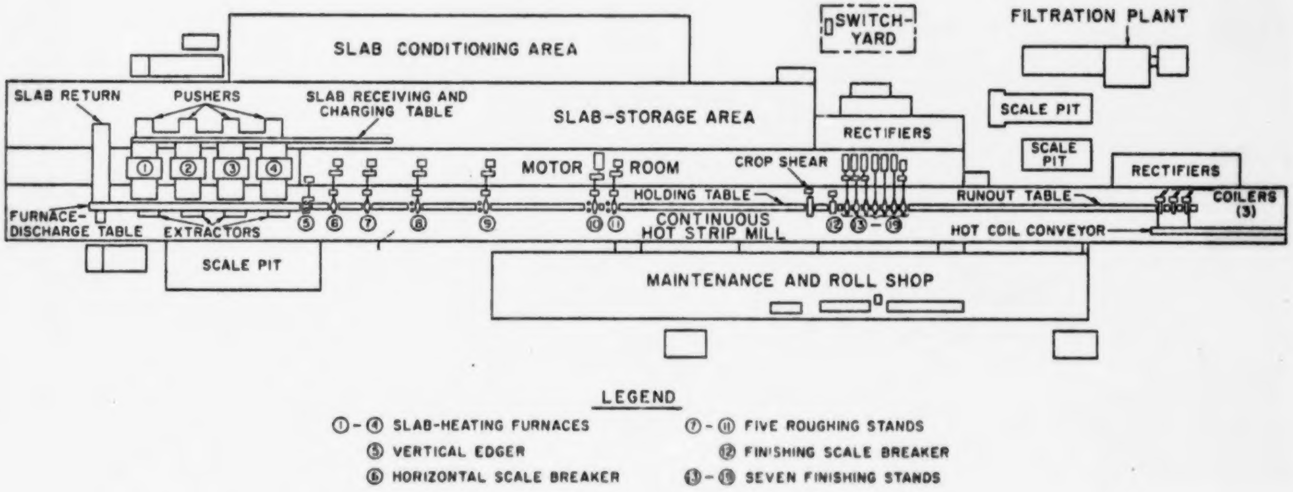
The 84 inch continuous hot strip mill's principal operating units layout is illustrated in Figure 4-4. A detailed description of U.S. Steel Gary Works' 84 inch hot strip mill is given in Chapter 32 of The Making, Shaping, and Treating of Steel.

4.2.1 FUGITIVE HYDROCARBON EMISSION SAMPLING

The hydrocarbon sampling program was performed at the U.S. Steel Gary Works' 84 inch hot strip mill in early March, 1979. No rolling oil was used during the hot reduction operation due to winter damage to the mill's coolant/lubricant application system.

A portable organic vapor analyzer, Century Systems' Model OVA-108, was used for the hydrocarbon emission monitoring. The exhaust from the hot roll reductions operations area is emitted directly to the ambient (building) atmosphere. The hot mill complex is not equipped with any central air evacuation systems and no central stack duct exists. All vapors generated by the process eventually exit through

Figure 4-4. 84 INCH HOT STRIP MILL, GARY WORKS


SLAB CONDITIONING AREA
SWITCH-YARD
FILTRATION PLANT
SLAB RETURN
PUSHERS
SLAB RECEIVING AND CHARGING TABLE
SLAB-STORAGE AREA
RECTIFIERS
SCALE PIT
SCALE PIT
RECTIFIERS
① ② ③ ④
MOTOR ROOM
CROP SHEAR
HOLDING TABLE
RUNOUT TABLE
COILERS (3)
FURNACE-DISCHARGE TABLE
EXTRACTORS
⑤ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪
CONTINUOUS HOT STRIP MILL
⑫ ⑬-⑲
HOT COIL CONVEYOR
SCALE PIT
MAINTENANCE AND ROLL SHOP
LEGEND
①-④ SLAB-HEATING FURNACES
⑤ VERTICAL EDGER
⑥ HORIZONTAL SCALE BREAKER
⑦-⑪ FIVE ROUGHING STANDS
⑫ FINISHING SCALE BREAKER
⑬-⑲ SEVEN FINISHING STANDS

Reproduced from "The Making, Shaping and Treating of Steel", Ninth Edition,
©Copyright 1971 by United States Steel Corporation.

NTIS is authorized to reproduce and sell this report. Permission for further reproduction must be obtained from the copyright proprietor.

roof monitors located directly over each of the mill stands. The roof monitors also serve as a ventilation system for the entire mill. Under the prevailing circumstances, it was decided that the portable hydrocarbon analyzer was the best device to monitor hydrocarbon emissions. It was decided, for safety reasons, to monitor hydrocarbon emissions only across the finishing stands. Mill personnel stated that sampling at the roughing stands and at other ancillary equipment would place the sampling personnel in an excessively unsafe position. The OVA-108 analyzer was selected as the only logical instrument for use, due to safety considerations (i.e., its size and portability). The portable hydrocarbon analyzer operates on the principle of flame ionization detection and has been certified as intrinsically safe by Factory Mutual Research Corporation (FMRC). The analyzer was calibrated prior to the monitoring to assure accuracy.

4.2.2 HYDROCARBON EMISSIONS FROM 84 INCH HOT STRIP MILL FINISHING STAND AREA

Total hydrocarbon compounds (as methane) emitted into the atmosphere of the mill operations building above the finishing stands area ranged between 7 ppm and 23 ppm. The emission monitoring results are tabulated in Table 4-2.

The total hydrocarbon concentration in the air above the finishing stands area, averaged over the entire period of monitoring, was 18 ppm (including a 3 ppm background concentration).

The seven finishing stands are spaced 5.5 m (18 ft) from each other. The average steel strip width rolled through these mills is 199 cm (47 in). A schematic of the finishing stands area is presented in Figure 4-5. The speed at which the steel strip travels after each stand differs, increasing in magnitude as the strip travels in a forward direction. The entrance temperature of steel strip before the first stand is greater than 871°C (1,600 °F), and the exit temperature is in the vicinity of 704°C (1,300°F). These temperatures are much higher than the fire points of typical lubricant oils used as rolling oil solutions.

Table 4-2. FUGITIVE HC MONITORING ACROSS THE FINISHING STANDS AREA OF 84 INCH HSM, U.S. STEEL, GARY WORKS

Location: Finishing Stand No. 1, 2, 3, 4, (combined)

Time (every 2 minutes)	Hydrocarbon, ppm (stable for 2 min)	Low (instant)	High (instant)
10:00 a.m.	10	7	23
10:02	10	10	20
10:04	15	15	18
10:06	10	10	17
10:08	15	8	21

Location: Finishing Stand No. 4, 5, 6, 7 (combined)

10:08 a.m.	20	8	23
10:10	16	15	21
10:12	19	7	20
10:14	20	8	23
10:16	15	10	15

Location: 84 inch Hot Strip Mill
Finishing Stands Area

Plant: U.S. Steel, Gary Works, Gary

Operators: PES and U.S. Steel, Dept. of Environmental Control

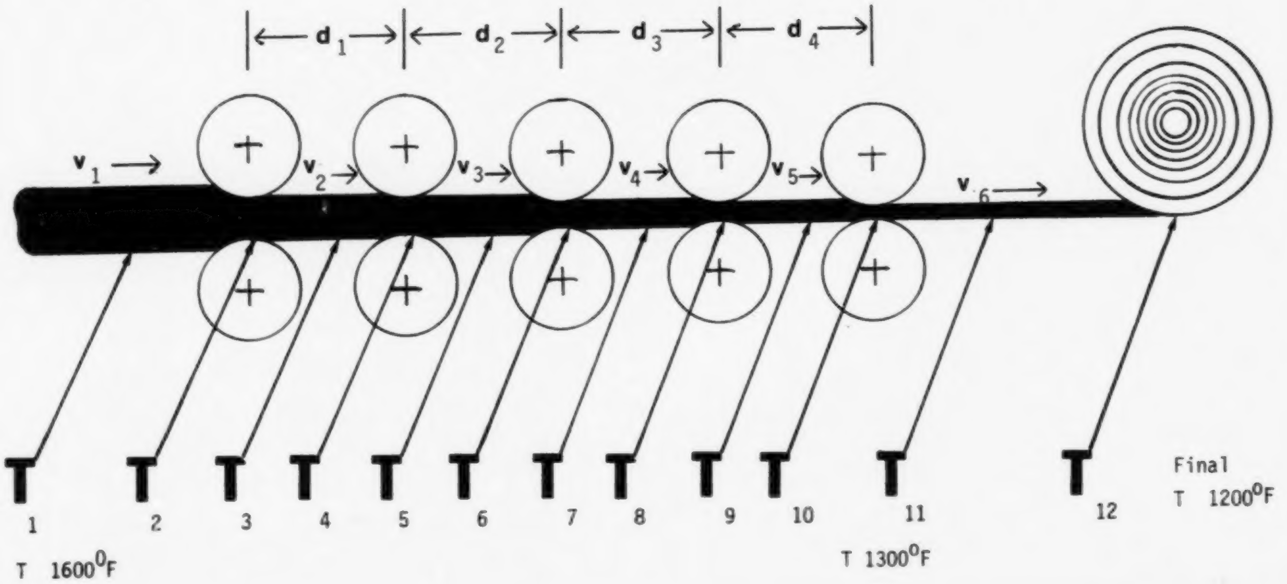
Date: 3/9/79

Building Temperature: 70°F

Barometric Pressure: 29.92 inch Hg

Figure 4-5. HOT STRIP ROLLING MILL PARAMETERS ACROSS FINISHING STANDS

V_x = strip velocity
d_y = distance between two consecutive mill stands
T_z = strip temperature



d1
d2
d3
d4
v1
v2
v3
v4
v5
v6
1
2
3
4
5
6
7
8
9
10
11
12
T 1600°F
T 1300°F
Final
T 1200°F

4.2.2.1 Basis for Emission Rate Calculation

The absence of a duct in which to make emission measurements and constraints caused by safety considerations and the physical conditions at the hot strip mill made direct measurement of emissions from the hot strip mill difficult. As a consequence, only limited data was gathered. Using the limited data, estimated emission rates were calculated by three independent methods. These methods are described below.

4.2.2.2 Method 1

Calculation for this method is based on a rectangular steel strip with rolling oil film on its surface traveling with a speed of $\underline{v}$ feet per second. The steel strip is 18 ft. long (equal to the distance between two consecutive finishing stands) and 47.25 inch wide (equal to the average width of the steel strip rolled through the finishing stands).

The results of the amient monitoring of total hydrocarbon emissions to the air over the finishing stands area indicated a 18 ppm average, during the monitoring period measured, at a height of 9 feet above the strip. Since the mill building background hydrocarbon concentration was 3 ppm, the approximate portion due to direct emissions from that strip was 15 pm. It was assumed that the total hydrocarbon concentration measured at 9 feet above the strip was the average over a height 9 feet above and below the sampling point. The average evaporation of oil into the ambient air at the finishing stands can thus be visualized as a layer 18 ft. high by 47.25 in. wide having a concentration of 15 pm traveling at the speed of $\underline{v}$ feet per second.

The actual speed of the air layer over the rolling mill is probably less than the speed of the strip, causing a positive error in the estimate of overall hydrocarbon emissions. However, since the dilution air and the hydrocarbon emissions escaping the area used in the estimate tend to reduce the hydrocarbon emissions at the point of sampling, the assumption of an average direct emission concentration of 15 ppm through a depth of 18 ft (9 ft above and below sample probe) was deemed acceptable. By using these assumptions, an annual hydrocarbon emission rate of 42 ton/year was calculated for the 84 inch hot strip mill operating under the conditions present during sampling. However, the conditions were not typical. The major source of hydrocarbons into the system, the rolling solution application for the mill, was not in operation immediately prior and during the time of the test. Therefore, these emissions appear to be from lubricant leakage from stand equipment and trace oil contained in the mill cooling water. If rolling oils had been in normal use, the total hydrocarbon emission rate is expected to have been higher. Also since these figures are based on one sampling at one mill, not operating under normal conditions, the resultant emission factor is a rough estimate, even if applied to mills of similar design and operating characteristics.

The following hydrocarbon emission rate calculations are the basis of the method one estimate.

84 Inch Hot Strip Mill

Installed capacity:	4.4×10^6 tons/year
Utilized Capacity:	2.83×10^6 tons/hr
Steel density:	40.8 lb/sq ft/inch of thickness
Average thickness of final products:	0.2735 inch
Sampling point height:	9 ft
Average width of final products:	47.25 inch

Speed of the steel strip travel:

No. of Stand	1	2	3	4	5	6	7
Speed ft/sec	5.3	8.33	11.93	15.53	15.53	24.87	24.87

(Ref: "The Making, Shaping and Treating of Steel")

Rolling oil was not applied on the finishing stands.

Displaced volume:

$$= \text{width} \times \text{height} \times \text{speed}$$

$$= \frac{47.25}{12} \text{ ft} \times 18 \text{ ft} \times \underline{v} \text{ ft/sec}$$

$$= 70.875 \times (\underline{v}) \text{ ft}^3\text{/sec}$$

Volumetric flow rate: Assuming a total operating time of 64%

$$= 70.875x(v)ft^3/sec \times 3.1536x10^7 sec/yr \times 0.64$$

$$= 1.43 \times 10^9 \times (v)\ ft^3/yr$$

Avg. temperature: 70^oF (530^oR)

Pressure: 1 atmos

$$1\ lb\ mole\ gas\ (70^oF,\ 1\ atmos) = 359\ cu\ ft \times \left(\frac{460 + 70}{460 + 32}\right) = 387\ cu\ ft$$

$$\text{Molar flow rate} = \frac{1.43 \times 10^9 \times (v)\ ft^3/yr}{387\ cu\ ft/lb\ mole} = 3.696 \times 10^6 x(v) lb\ moles/yr$$

Average Hydrocarbon Direct Emission Concentration (expressed as CH_4)

$$= 18\ ppm - 3\ ppm = 15\ ppm$$

$$\text{Hydrocarbons emission rate} = (3.696 \times 10^6)(v)(15/10^6)\ lb\ moles/yr$$

$$= (3.696 \times 10^6)(v)(15/10^6)\ (16\ lb/lb\ moles)\ lbs/yr$$

$$= (3.696 \times 10^6)(v)(15/10^6)\ (16\ lb/lb\ moles)(ton/2000\ lbs)\ tons/yr$$

$$= 0.4436 \times (v)\ tons/yr$$

Substituting the value of the steel strip travel speed v into the above equation, hydrocarbon emissions from each of the stands is calculated to be:

No. of Stand	1	2	3	4	5	6	7
Hydrocarbon emissions tons/yr	2.35	3.7	5.29	6.89	6.89	11.0	11.0

Summing emissions from seven stands yields a yearly emission rate of: 42.8 MT (47.1 ton)

4.2.2.3 Method 2

This method uses the background hydrocarbon concentration of 3 ppm measured at floor level, approximately 30 meters (100 feet) from the hot strip finishing stands. Emission testing at the roof monitors was not possible. If one assumes this is the exit concentration of hydrocarbons at the roof monitors, the following calculation can be made.

The approximate air volume in the finishing stand area equals the length of the finishing stand section plus 30 meters (100 feet) on either end of the stands; times the width of the strip plus 30 meters (100 feet) on either side of the strip; times the height of the building's roof monitors. The above distances were derived from the fact that both the roof monitor elevation and the sample point distance were approximatley 30 meters. The calculation yeilds:
$(100 + 100 + 125)\text{ft} \times (100 + 100 + 4)\text{ft} \times 100\text{ ft} = 6.6 \times 10^6\text{ ft}^3$

Hot strip mill buildings are designed for air exchanges rates in the range of 12 to 25 air exchanges per hour. For 12 air exchanges per hour:
$6.6 \times 10^6\text{ ft}^3 \times 12\text{ exchanges/hr} \times 24\text{ hr/day} \times 365\text{ day/yr} \times .64 =$
$4.4 \times 10^{11}\text{ ft}^3\text{/yr}$

Therefore, approximately $4.4 \times 10^{11}\text{ ft}^3\text{/yr}$ of air containing 3 ppm of hydrocarbons are exhausted from the finishing stand area yearly. As in the previous calculation, the molar flow rate equals:

$$\frac{4.4 \times 10^{11}\text{ft}^3\text{yr}}{387\text{ cu ft/lb mole}} = 1.1 \times 10^9\text{ lb mole/yr}$$

The average hydrocarbon concentrations expressed as CH_4 is 3 ppm.

Therefore, the yearly hydrocarbon emission rate at 12 air exchanges per hour is:

$$\frac{(1.1 \times 10^9\text{ lb mole/yr})\ (3/10^6)\ (16\text{ lb/lb mole})}{2000\text{ lb/ton}} = 24.0\text{ MT } (26.4\text{ Ton})$$

At 25 air exchange per hour, the yearly hydrocarbon emission rate is:
$24\text{ MT/yr}(\frac{25}{12}) = 50.0\text{ MT/yr.}\ \ (55.1\text{ ton/yr})$

4.2.2.4 Method 3

This method is based on an estimate of water evaporated from the hot strip mill. Most large hot strip mill finishing stands use between 38,000 and 76,000 liters per minute (10,000 to 20,000 gallons per minute) of water as a coolant and lubricant for the rolls. Samples of the finishing stand effluent water streams were taken at the 84 inch hot strip mill. These samples showed that the water contained 27 ppm oil. Since the temperature of the hot strip is well in excess of 540°C (1,000°F), PES engineers assumed that between 0.5 and 5 percent of the water sprayed on the hot strip mill would evaporate. This assumption was necessary since no accurate data on coolant water evaporation was available from any of the participating mills. It was also assumed that the evaporated water contained 27 ppm oil. The calculations yield:

$$(38{,}000\ \mathrm{l/min})(27 \times 10^{-6}\mathrm{kg/l})(525{,}600\ \mathrm{min/yr})(0.64)(0.005) = 1.7\mathrm{x}10^{3}\mathrm{kg/yr}$$

$$(76{,}000\ \mathrm{l/min})(27 \times 10^{-6}\mathrm{kg/l})(525{,}600\ \mathrm{min/yr})(0.64)(0.05) = 3.5\mathrm{x}10^{4}\mathrm{kg/yr}$$

Therefore, this method estimates emissions of 1.7MT (1.9 ton) to 35MT (38.5 ton) per year of hydrocarbons.

4.2.2.5 Discussion

Since insufficient data was collected to enable more direct and precise calculation of these emissions, several different methods were used to estimate emissions so that the variability of the estimates could be considered. Methods one and two, dealing directly with the air media, resulted in estimates that have relatively close agreement. Method three involves a phase change from liquid to gas and includes two estimated variables, one with a factor of 2 range, and the other with an order of magnitude range. Incorporating these two variables into the calculations produces estimates with a factor of 20 range, which includes some common range with the estimate produced by Method 2. Since the rolling solution application system was not operational at the time of sampling, the data and estimates of emissions are more representative of hot strip mills that do not add rolling oils. Large quantities of lubricants are used in these mills and some is washed into the water, especially from older machinery that is more lubricant intensive.

However, at the mills applying additional oil, through their rolling solution application systems, emissions would be expected to increase as the oil concentration in the contact water increases. Also, it is expected that different rolling oil formulations and operating variables from mill to mill would result in significant variability of emissions. Future sampling should include mills operating with rolling solution application systems and collect sufficient data to enable a more direct calculation of total emissions from this source. Since Method 1 and 2 are based on directly measured hydrocarbon concentrations in the air and have reasonably close agreement, and method 1 utilized the most directly measured data and produces an estimate that falls within the range produced by Method 2, the remainder of the report will be based on emission estimates generated by Method 1.

4.2.3 GRAB SAMPLES

In addition to the continuous monitoring of total hydrocarbons emitted from the finishing stands area, three building air grab samples were collected over the sixth (one sample) and seventh(two samples) finishing stands. Standard Recommended Practice for "Sampling Atmospheres for Analysis of Gases and Vapors" issued under the fixed designation D1605-60 (Reapproved 1973) by American Society for Testing and Materials (ASTM) was referenced and the type of sampling method - Sampling Atmospheres With Concentration of Gases and Vapors - was specifically followed.

The gas sample tubes (Type B), as shown in Figure 4-3 and previously described, were used. The sample tubes were made from an inert glass material and had a 250 cc capacity. When the sample tube is evacuated, both stopcocks remain open. One end is connected to the vacuum pump and the other end is connected to a vacuum gauge. Both stopcocks are greased to increase gas tightness. Once the vacuum manometer registered 26.5 inch Hg vacuum, it was assumed that the original air or gas was completely swept out by the vacuum pump, and then the stopcocks were closed. General precautions against leaks were taken during the entire sampling period. To collect grab samples, the evacuated tube was placed over the hot strip (9 ft over strip) and one stopcock was opened. The surrounding atmosphere immediately entered and filled the tube to atmospheric pressure. One sample was collected between stands 5 and 6 and two samples were taken between stands 6 and 7. The grab samples were further analyzed for chemical composition/hydrocarbon species at a remote laboratory.

In addition to these grab samples, water samples were also collected at the following six locations of the 84 inch hot strip mill:

- 84 Inch Hot Strip Roughing Stand Effluent
- 84 Inch Hot Strip Finish Stand Effluent
- 84 Inch Hot Strip Roughing and Finish Stand Influent
- 84 Inch Roughing Stand Scale
- 84 Inch Hot Strip Sludge
- No. 6 Cold Stand Rolling Emissions*

These samples were gathered to determine the loss factors associated with the wastewater streams of the mill.

4.2.4 CHEMICAL ANALYSIS

All of the grab samples collected during the monitoring were analyzed for total quantity and characteristics of the resultant hydrocarbon emissions. Water samples were analyzed for total oil content. The sample preparation has been described previously in Section 4.1.5.

Summary:

Chemical analysis of the air grab samples indicated that the total oil content was less than the minimum detectable limit of the laboratory analytical equipment (10×10^{-6} gms/250cc or 29 ppm as methane). The average reading obtained in the field with the portable analyzer was 15 ppm. Therefore, the grab sample hydrocarbon concentration would be expected to be less than the minimum detectable limit (29 ppm) of the laboratory equipment used to analyze the grab samples. Further identification of hydrocarbon species emitted from the finishing stands area at the hot strip mill was not attempted due to low concentration in the grab samples.

---

* Not part of Hot Strip Mill

The following calculation illustrates the conversion to parts per million for the grab sample.

Total HC (as methane) concentration 10×10^{-6} gms/250 c.c.

i.e., 40×10^{-6} gms/1000 c.c. = maximum concentration

Conversion of air volume into air weight:

$$\frac{1000\ \text{c.c. air}}{1000\ \text{c.c./liter}} \times \frac{28.84\ \text{gm}}{\text{g-mole}} \times \frac{\text{g-mole}}{22.4\ \text{liter}} \times \frac{530^{\circ}\text{R}}{492^{\circ}\text{R}}$$

$$= 1.387\ \text{gm air/1000 c.c. air}$$

$$\text{ppm} = \frac{40 \times 10^{-6}\text{gm CH}_4\text{/1000 c.c. air}}{1.387\ \text{gm air/1000 c.c. air}} \times \frac{10^6}{10^6}$$

$$\text{ppm} = 28.84$$

$$= 29$$

The measured concentration (15 ppm with the portable analyzer or less than 29 ppm in the grab samples) is thought to be lower than would be found at a "typical" hot strip mill since no rolling oil was being used at the time that the sampling occurred.

Table 4-3 is a summary of the hydrocarbon concentrations for the samples collected.

4.3 LABORATORY SIMULATION OF ROLLING OIL VOLATILIZATION

A simulated laboratory experiment was designed for determination of hydrocarbons released from volatilization and/or decomposition of rolling oil on hot steel. A representative sample of rolling oil (oil content = 3.3 percent by weight) was collected at the U. S. Steel Gary Works and analyzed.

Table 4-3. SUMMARY OF HYDROCARBON ANALYSIS

SAMPLE	TOTAL OIL	ALIPHATIC HYDROCARBONS	OLEFINIC HYDROCARBONS	POLAR LIPIDS
Air Sample #1	< 10 ugs	--	--	--
Air Sample #2	< 10 ugs	--	--	--
Air Sample #3	< 10 ugs	--	--	--
#6 Stand Palm Oil	3.3 %	--	--	3.3 %
Roughing Stand Effluent	< 10 mg/l	--	--	--
84" Finish Stand Effluent	27 mg/l	--	--	--
Service Water Inlet	< 10 mg/l	--	--	--
Rolling Stand Scale	0.53 %	--	--	0.53 %
84" Hot Strip Scale	18.8 %	--	--	18.8 %

The object of the experiment was to determine what hydrocarbons and what quantities of hydrocarbons are released when rolling oil solution (emulsion of water and oil) comes in contact with the hot steel. The experiments were conducted at 600^{o}F, 800^{o}F, 1200^{o}F, 1600^{o}F, and 2000^{o}F.

4.3.1 EQUIPMENT

Equipment used to conduct the experiment were:

1. 4 inch x 4 inch stainless steel plate, electrically heated and its temperature measured by thermocouple
2. Bubbler trap for collecting hydrocarbon emissions

Gas-liquid chromatograph was used to identify and quantify aliphatic hydrocarbons. Figure 4-6 illustrates the collection apparatus used during the experiment.

4.3.2 PROCEDURE

The procedure was as follows:

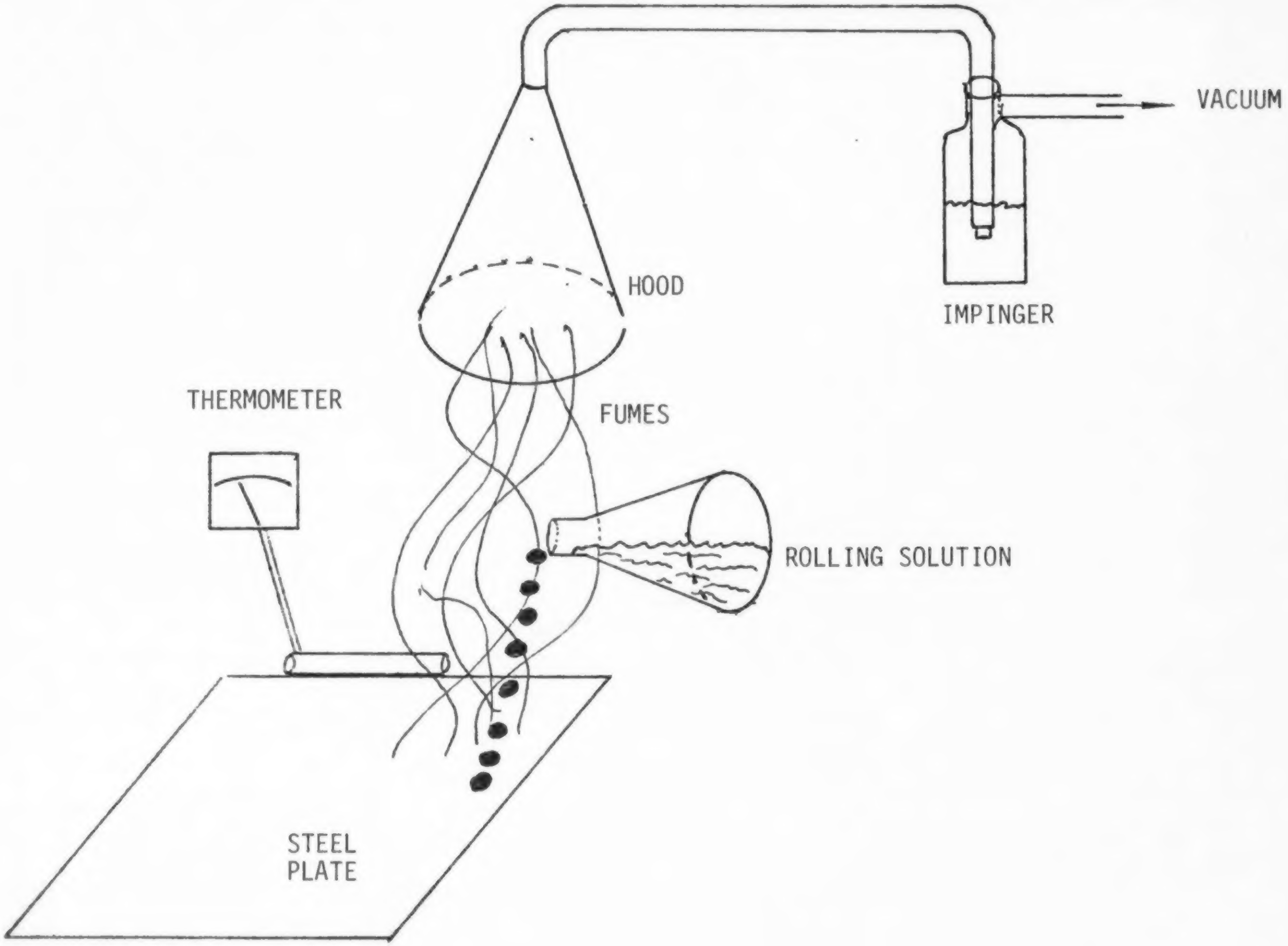
1. The steel plate was heated to the appropriate temperature.
2. Fumes released by volatilization and/or decomposition from the oil were collected into a bubbler by vacuum aspiration.
3. A chromatographic analysis was performed on the collected emissions.

4.3.3 DISCUSSION OF RESULTS

The detailed chemical analysis report is presented in Appendix C. The results of the laboratory simulation experiments are as follows:

1. All hydrocarbons that volatilized from the rolling oil in this experiment were aliphatic (saturated).
2. The hydrocarbons volatilized ranged from C-6 and lower to C-34.
3. Percentage of total rolling oil volatilized in these six experimental test sets ranged from 30 percent to 50 percent.

Figure 4-6. ROLLING OIL VOLATILIZATION LAB SIMULATION COLLECTION APPARATUS


VACUUM
HOOD
IMPINGER
THERMOMETER
FUMES
ROLLING SOLUTION
STEEL PLATE

4. A portion of the oil taken in each experimental set was carbonized.
5. Percentage of C-6 and lower hydrocarbons in all volatilized aliphatic hydrocarbons ranged from 0.4 percent to 1.19 percent.
6. Hydrocarbons volatilized in significant (greater than 2 percent) amounts were C-14, C-15, C-18, C-25, C-26, C-28, and C-30.
7. Hydrocarbons volatilized in insignificant amounts were C-8, C-10, C-12, C-13, C-19, C-21, C-23, C-32, and C-34.
8. No direct correlation between temperature and volatilized hydrocarbons, either by quantity or type was found.

At the lower temperatures, (600°F to 1200°F) the oil would ignite on contact with the steel; at the higher temperatures (greater than 1200°F), the oil would bead up before it would burn. Also, at higher temperatures, the tubing in the collection system became very warm and evidently released some of the plasticizers as can be seen in the "contaminants" peaks on some of the chromatograms.

The correlation of the laboratory analysis at 600°F does, however, parallel the results of the stack sampling performed at the 56 inch and 80 inch cold strip mills at Inland Steel. The operating temperature of the rolls of the cold mills is assumed to be from 400°F to 600°F. As can be seen in Table 4-4, one similar aspect of the resulting decomposition of the rolling oils is that the majority of aliphatic hydrocarbons are in the C-14 through C-19 range (49 to 81 percent). No determination as to the relative reactivity of these resultant hydrocarbon species was attempted.

A major difference between the results of the laboratory simulation and the actual results received from the cold mill samples was the percentage of total aliphatic hydrocarbons. In the laboratory simulation, the polar lipids were broken down completely to aliphatic carbon chains. Whereas in the case of the cold mill sample, (56 inch mill) approximately 33 percent of the total volatilized portion were aliphatic in nature with the remainder being olefinic hydrocarbons (39 percent) and polar lipid materials (23 percent).

Table 4-4. COMPARISON OF STACK SAMPLE ANALYSIS (COLD MILL) VERSUS LABORATORY SIMULATION AT 600°F

Type of Aliphatic Hydrocarbons	Percent of Total Hydrocarbons Captured in Sample					
	56 inch Mill		80 inch Mill		Lab Simulation	
C-6 and lower	--		--		1.2	
C-8	--		--		0.5	
C-10	--		--		0.5	
C-12	--		--		0.8	
C-13	--		--		1.3	
C-14	5.8	64.9	2.0	48.5	14.3	80.5
C-15	7.6		6.6		21.4	
C-16	12.1		6.1		4.3	
C-17	13.6		9.2		3.2	
C-18	15.4		10.6		37.3	
C-19	10.4		14.3		--	
C-20	5.6		9.8		--	
C-21	8.3		7.6		--	
C-22	5.8		4.7		--	
C-23	4.5		6.9		--	
C-24	3.3		6.6		--	
C-25	3.8		5.9		--	
C-26	3.8		4.8		7.2	
C-28	2.0		6.7		--	
C-30	2.0		2.0		2.1	
C-32	2.0		2.0		5.8	
C-34	2.0		2.0		--	
C-36	2.0		2.0		--	
C-38	2.0		2.0		--	

5.0 DATA ANALYSIS

5.1 METHODOLOGY FOR DATA ANALYSIS

The principle objective of the survey was to analyze data drawn from questionnaires completed by five steel mills, use this information to develop material balance estimates, and then to identify the use and fate of lubricants, oils, greases and hydraulic fluids in the finishing process of the steel industry. Since there are a number of distinct finishing processes, each individual finishing mill must be analyzed as a separate entity.

As the questionnaire responses were received, it became clear that the responses generally lacked the degree of detail required for the project, particularly for developing material balance estimates. Due to this fact, much of the data utilized for the mass balances presented in this section were obtained during the facility visits.

5.2 FACTORS AFFECTING LUBRICANT USAGE AND FATE

Several factors were identified that influence lubricant use rates and their fates. These factors are discussed so that the reader can appreciate the limits of the data and the problems of the material balance development. As a result of these factors, potentially significant errors are encountered when data from different steel mills is extrapolated to make industry-wide generalizations. Generally, despite the cooperation of mill personnel, sufficient data to develop material balances for total or specific oils, greases and hydraulic fluids does not exist. Few, if any, mills have studied the problem in detail. Engineers of United States Steel Gary Works have tried to conduct an in house lubrication mass balance over their facility and have stated that the information required is not regularly recorded, and thus generally unavailable.

The most obvious factors influencing lubricant use and fate are the size, design, and age of the steel mill equipment. A great variety of equipment and major differences in the age and production capacity exists in the American steel industry. The lubrication practices and application methods also vary as widely. These factors, as well as maintenance and housekeeping practices, influence the amounts and types of lubricants applied and, to some extent, the fate of these lubricants. Also different amounts of a variety of steel products are produced at different steel mills. Waste oil collection and reclamation efforts also differ widely from one mill to another. Currently, most steel mills are primarily trying to prevent excessive oil and grease discharge rates (as specified in NPDES permits). Other mills are engaged in programs aimed at recovery and reclamation of waste oil. The responsibilities of the lubrication, environmental, maintenance, and operating departments vary at the different steel mills, and the sensitivity and awareness of maintenance and operating personnel significantly affect efforts to conserve and recover lubricants and hydraulic fluids.

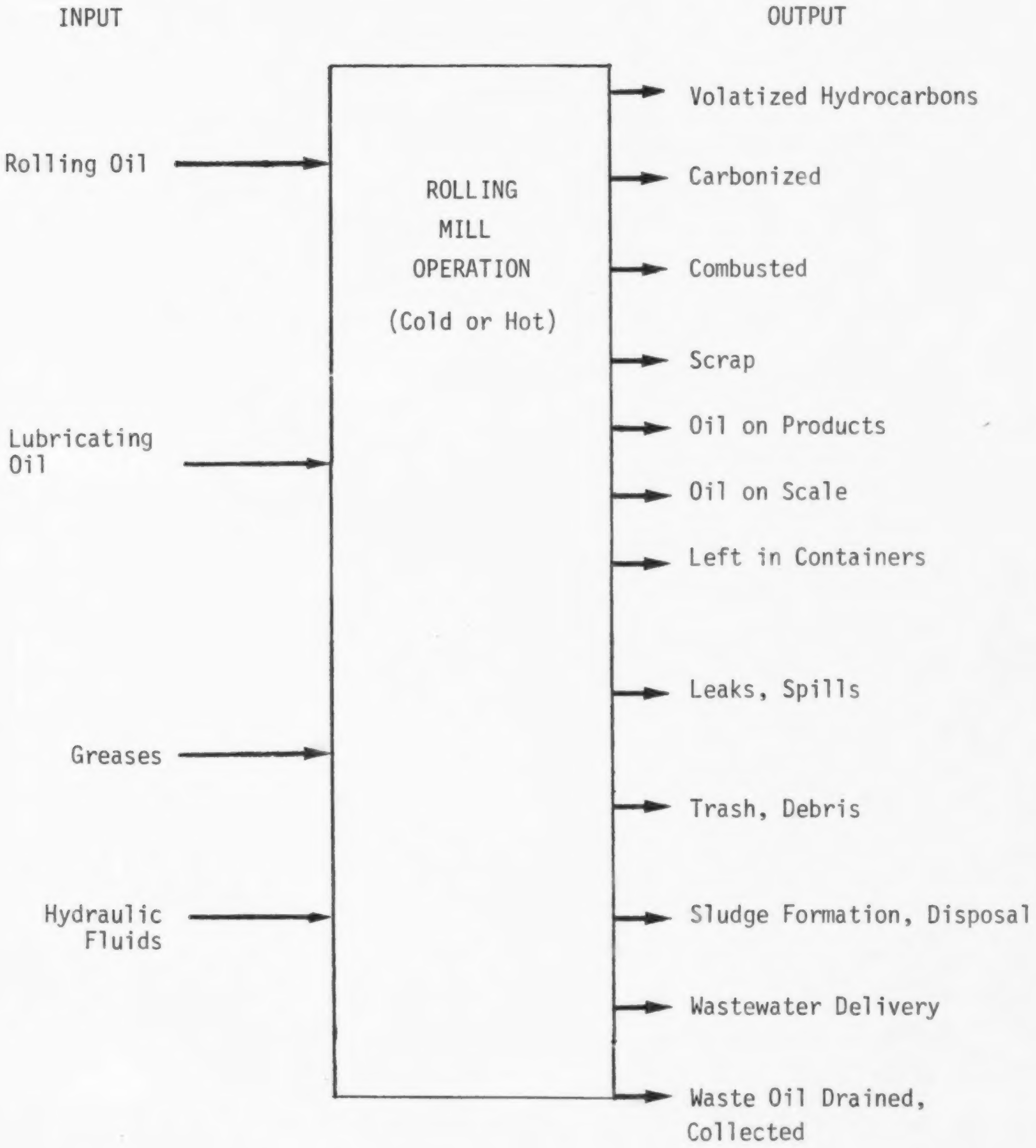
The basic components needed to complete a mass balance over a hot strip mill are illustrated in Figure 5-1. The four basic lubricant types are:

1) Rolling oil - oil used in the rolling process for reducing power consumption and roll wear, improving product quality, and improving overall mill efficiency.

2) Lubricating oil - used for the protection of moving machinery. A basic list of oils used includes: engine oils, extreme pressure oils (EP), rust and oxidation inhibiting (R & O) oils, and protective coating oil.

3) Greases - generally used under the following conditions: a) where there is no way to retain oil for the parts being lubricated; b) when the lubricant must act as a seal to prevent the entrance of dirt; c) when a lubricant is seldom added; and d) where speeds are low and pressures are high.

Figure 5-1. BASIC COMPONENTS OF ROLLING MILL OIL MASS BALANCE


INPUT
OUTPUT
Rolling Oil
Lubricating Oil
Greases
Hydraulic Fluids
ROLLING MILL OPERATION
(Cold or Hot)
Volatized Hydrocarbons
Carbonized
Combusted
Scrap
Oil on Products
Oil on Scale
Left in Containers
Leaks, Spills
Trash, Debris
Sludge Formation, Disposal
Wastewater Delivery
Waste Oil Drained, Collected

Generic grease categories are: extreme pressure (EP), molybdenum disulfide, roller bearing, roll neck, extra duty EP, high temperature EP, mill utility, cup, and block greases.

4) Hydraulic fluids - generally oil-based products which come in slightly less variety than lubricating oils and greases. Some typical products in use include: inverted emulsions, phosphate ester, water-glycol, inhibited hydraulic, and extra-duty anti-wear hydraulic fluids.

A complete chemical analysis of all of the above input terms can be found in Appendix A. All lubricant use data included as input data were reported on an individual mill basis.

The potential output products are not as clearly specified as the input materals. Factors such as leaks and spills are not well defined, but in most cases estimates were provided for these parameters, hereafter called terms. The following terms are used to define the output flows in the mass balances:

1) Volatilized Hydrocarbons:

"Volatilized Hydrocarbons" is defined as the emission of hydrocarbons due to volatilization of rolling oils, lubricants, greases, and hydraulic fluids used in rolling operations in cold strip mills or hot strip mills.

In cold strip mills, steel at ambient temperature is passed through a series of rolls and reduced in thickness (cold reduction process). Frictional forces are developed which cause a rise in temperature of the steel strip and steel rolls. This results in the decomposition of the lubricant in rolling oil solution into hydrocarbons and eventual volatilization into the ambient atmosphere.

In hot strip mills, the steel rolling temperature ranges between 700°C and 1300°C (1300°F - 2400°F). The higher temperature, as compared to cold strip mills, causes a greater decomposition of the lubricants into hydrocarbons, and a correspondingly higher emission of organic compounds.

2) Carbonized:

"Carbonized" is defined as the fraction of lubricants in a rolling oil solution used on hot strip mills that is carbonized into graphitic form. The high temperatures (700°C - 1300°C (1300°F - 2400°F)) and pressures combined with oxygen for combustion result in the carbonization of a portion of rolling lubricant. The solid graphitic carbon formed acts as a solid lubricant over the work rolls.

3) Combusted:

The term "combusted" is the fraction of lubricant in rolling oil solution combusted into carbon dioxide and water vapor. In hot strip mills, very high temperatures (700°C-1300°C (1300°F-2400°F)) are encountered during hot reduction which result in the combustion of a portion of the lubricant. Combustion was not considered in cold rolling due to lower temperatures (260°C (500°F)).

4) Scrap:

The amount of oil left on rejected product is termed "oil on scrap." This steel is recycled back to Basic Oxygen Process (BOP) shops.

5) Oil on Products:

The amount of oil left on the surface of the strip is termed as "oil on products". Significant quantities of oils and greases leave the steel mill on each product. Oils and greases may remain on the product following rolling operation, or it may be applied for rust protection.

6) Oil on scales:

The amount of oil left on surfaces of scales is termed as "oil on scales". In hot strip mills, steel heated in slab-heating furnaces (700°C-1300°C (1300°F-2400°F)) is passed through rolls and hot reduced in thickness. The surface layer of the steel strip is rapidly oxidized by ambient oxygen. The resulting scale is removed by scale breakers prior to entry to the finishing stands.

7) Left in containers:

The amount of oil, grease or lubricant left in containers or lost in storage and handling is termed as a "left in containers" loss. A considerable amount of oil is lost in this manner.

8) Leaks, spills:

The amount of oil, grease, or lubricant leaked or spilled on floors or other surfaces is termed a "leak, spill" loss. A small but not inconsequential amount of oil leaks and spills onto the ground, and is generally cleaned up and disposed of.

9) Trash, debris:

The amount of oil, grease or lubricant left on waste debris, or trash is termed a "trash, debris" loss.

10) Sludge formation, disposal:

Sludges generated in rolling operations are landfilled or stockpiled. The amount of lubricating oil associated with sludge and lost through disposal per unit production of steel is termed as "sludge formation, disposal" loss. The amount of this oil is significant and represents one of the major loss pathways.

11) Wastewater Losses:

Oil loss associated with wastewater delivered to treatment is termed as "wastewater losses". This is a significant oil loss term, as water is treated in the wastewater plant for oil recovery. Since the following mass balances are only around individual rolling mills and most wastewater treatment facilities treat water from two or more mills, an accurate oil recovery term on a per mill basis cannot be calculated. As much as 90 percent of the oil found in the wastewater delivered to the treatment plant may be recovered and reprocessed. For a more detailed discussion, refer to The Use and Fate of Lubricants, Oils. Greases, and Hydraulic Fluids in the Iron and Steel Industry (Ref. 2).

12) Waste oil drained, collected:

Constitutents of lubricating oils, which are complex mixtures of different hydrocarbons, combine slowly with oxygen in the air, and more rapidly at high temperatures. The slow combination of hydrocarbons with oxygen seriously affect the performance of the remaining unoxidized lubricant. Service conditions involving churning and splashing of the oil, and exposure to high temperatures increases the rate of oxidation. The amount of lubricants drained and collected for oil recovery per unit steel production is termed a "waste oil drained, collected" loss. Lubricants with low resistance to oxidation are changed frequently.

5.3 INLAND STEEL, EAST CHICAGO, INDIANA

A summary of the major rolling mills and products of the Inland Steel Indiana Harbor Works is presented in Table 5-1. This information is a summary of data provided in the AISI Directory of Iron and Steel Works. The actual production during the period corresponding to

Table 5-1. INLAND STEEL COMPANY - EAST CHICAGO, INDIANA

No.	Type of Mill	Annual Rolling Capacity	
3	Blooming (2 primary, 1 secondary	4,150,000	8,350,000 Net Tons
1	Slabbing	3,200,000	
1	Billet	1,000,000	
4	Bar	1,275,000	19,483,000 Net Tons
1	Structural	550,000	
1	Plate	280,000	
3	Hot Strip	6,500,000	
5	Strip - Cold reducing	5,925,000	
8	Coil - Cold finishing	4,188,000	
3	Sheet - Cold finishing	765,000	
30		27,833,000 NET TONS	

* Equipment and annual rolling capacity data from AISI Directory of Iron and Steel Works (1.0 ton = 907.2 kg).

lubrication use data was reported to be approximately 76 percent of the plant's rated capacity of 7.2 x 10^9 kg/yr (8.0 x 10^6 tons/yr) or 5.5 x 10^9 kg/yr (8.7 x 10^6 tons/yr).

Mass balances were performed for three mills at this facility: the 80 inch five-stand tandem cold reduction mill; the 56 inch four-stand tandem cold reduction mill; and the 80 inch hot strip mill. The two cold strip mills were later stack tested to determine actual volatile hydrocarbons generated by the rolling process.

5.3.1 80 INCH FIVE-STAND TANDEM COLD REDUCTION MILL

Table 5-2 outlines the basic process parameters for the 80 inch mill.

5.3.1.1 Lubricant Usage

Yearly lubricant usage at the 80 inch five-stand tandem mill were as follows: (see Figure 5-2)

Roll coolant (Tallow)	15 MT	(17 ton)
Back up heating oil	101 MT	(111 ton)
Gear oil	82 MT	(90 ton)
Misty oil	18 MT	(20 ton)
Total	216 MT	(238 ton)

Assuming a density of 0.9 kg/l (7.5 lb/gal) for oils, the total oil, grease, and hydraulic fluid input to the plant is 240,199 l/yr (63,453 gal/yr). An oil and grease consumption factor of 0.16 kg/MT of steel produced (0.31 lb/ton) is calculated from these values.

The roll lubricants (emulsion) used on the 80 inch mill are recirculated and have an oil content of 2.8 percent.

Table 5-2. 80 INCH FIVE-STAND TANDEM COLD REDUCTION MILL OPERATING AND LUBRICANT PARAMETERS (INLAND STEEL - INDIANA HARBOR WORKS)

Production: 1,391,353 MT/yr (1,533,678 tons/yr) (year 1977)

Density of steel: 40.8 lb/sq ft/1 inch (average)

Density of oils, greases or hydraulic fluids: 0.9 kg/liter (7.5 lb/gal) (average)

Output products (90 percent carbon steel) thickness:

Maximum 0.32 cm (0.13 inch)
Minimum 0.032 cm (0.013 inch)
Average 0.175 cm (0.069 inch)

Total number of working days: 176 days

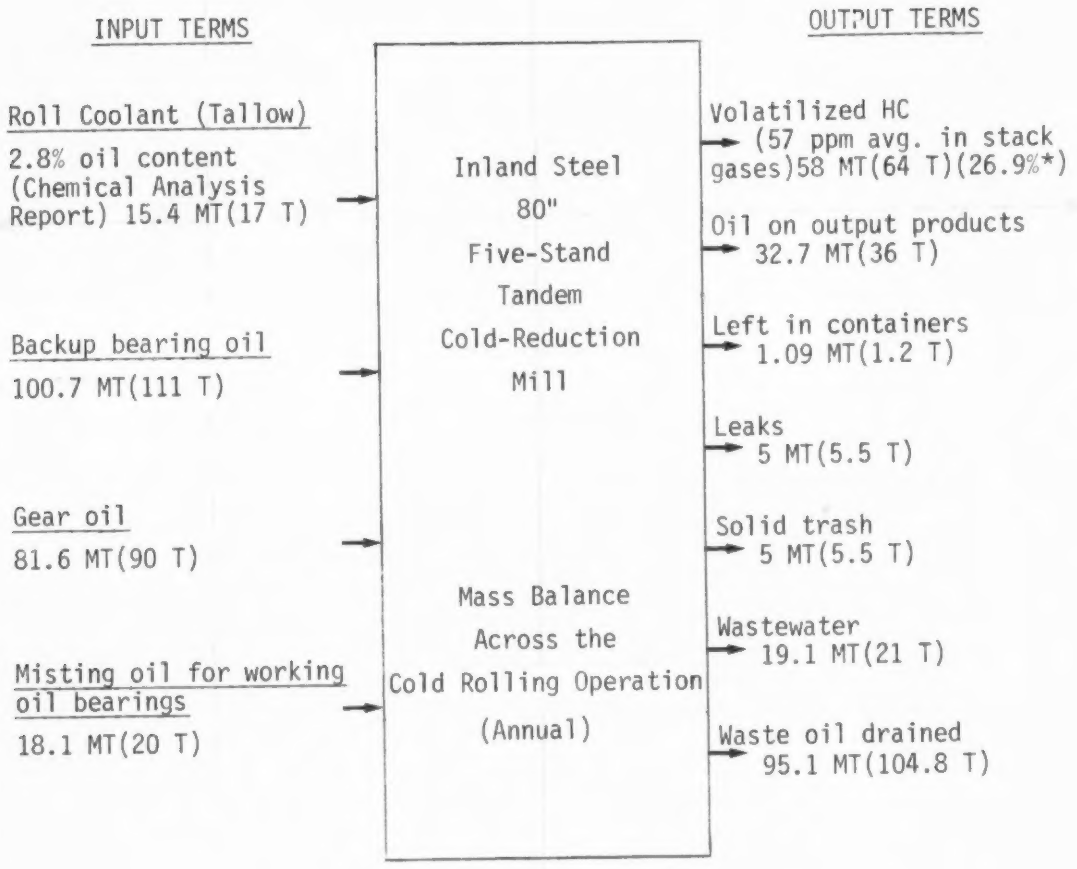
Resultant steel temperature: 65.55° - 121.11°C (150 - 250°F)

Cold reduction - No scale formation

Total lubricants (rolling oil, lubricant, grease and hydraulic fluid) required = 0.16 kg/MT (0.31 lb/ton)

Input = 216 MT (238 tons)   Output = 216 MT (238 tons)

Figure 5-2. COLD STRIP MILL LUBRICATION MASS BALANCE


INPUT TERMS
Roll Coolant (Tallow)
2.8% oil content (Chemical Analysis Report) 15.4 MT(17 T)
Backup bearing oil
100.7 MT(111 T)
Gear oil
81.6 MT(90 T)
Misting oil for working oil bearings
18.1 MT(20 T)
Inland Steel
80"
Five-Stand
Tandem
Cold-Reduction
Mill
Mass Balance
Across the
Cold Rolling Operation
(Annual)
OUTPUT TERMS
Volatilized HC (57 ppm avg. in stack gases)58 MT(64 T)(26.9%*)
Oil on output products 32.7 MT(36 T)
Left in containers 1.09 MT(1.2 T)
Leaks 5 MT(5.5 T)
Solid trash 5 MT(5.5 T)
Wastewater 19.1 MT(21 T)
Waste oil drained 95.1 MT(104.8 T)

* Percent of total output.

5.3.1.2 Discharges to Wastewater Treatment Facilities and Other Losses

Data on the average oil concentration in the wastewater discharge was not available; therefore, an estimation was derived by an article by Eugene J. Donovan Jr. in "Water and Waste Engineering." He estimated a typical oil analysis to be 500 mg/l. Since the recycle system underflow serves to concentrate undesirable oils and contaminants from the system centrifuges, floatation units, and other separation devices, the underflow concentration is relatively high as compared to the concentration used directly on the strip (between 40 and 90 mg/l). The average underflow rate is 151 l/min (40 gal/min). Incorporating these factors into the mass balance yields a total of 19.1 MT/yr (21 ton/yr) of oil delivered to the wastewater treatment plant (8.8 percent). This figure does not include emulsion/solution discharges which would substantially increase the flow rate for periods ranging from 15 to 60 minutes.

The terms left in containers; leaks, spills on ground floor; and solid trash were estimated to be 0.5 percent, 2.3 percent, and 2.3 percent of total lubricant used, respectively. These estimates were determined from data gathered from all the steel facilities involved in the project. It was assumed that these factors would remain essentially constant from mill to mill. The left in container term was derived from the following two values:

0.5 percent of oil and hydraulic fluid input (purchase)
5 percent of grease input (purchase)

These values were derived from the U.S. Steel, Gary Works' data made available to PES. Calculations based on these estimates yield an oil consumption factor of 1.1 MT/yr (1.2 tons/yr). The leaks and spills on ground floor terms were also estimated from the U.S. Steel, Gary Works' data as 0.004 kg/MT of steel produced (0.007 lb/ton). The last factor - solid trash and debris was determined to be 0.004 kg/MT of steel produced (0.007 lb/ton). This is also from the U.S. Steel, Gary Works' data. These estimations yield a consumption factor of 5.0 MT/yr (5.5 tons/yr) for leaks and spills, and the same value for solid trash and debris. Due to the nature of these three terms, the accuracy is probably low. However, these loss terms are comparatively small.

5.3.1.3 Material Balance

Estimates and generalizations have been made by PES for 80 inch five-stand tandem cold reduction mill in the following material balance.

Volatilized Hydrocarbons:

Hydrocarbon stack sampling was conducted at the discharge duct for quantification of total hydrocarbons (expressed as methane), and the identification of hydrocarbon species. The average concentration level found was 57 ppm, which results in annual emissions of 58 MT (64 tons/yr).

Oil on Output Products:

Available data indicated 15 milligrams of oil is lost as a surface film on every square foot of output product. The average thickness of final output products is 0.175 cm. 1977 steel production was 1.53×10^6 tons, and the average steel density assumed was 40.8 lb/sq ft/one inch thickness. From all these factors, the oil loss on final output products was estimated to be 33 MT/yr (36 tons/yr).

Waste oil drained and collected was estimated as the balance of the total loss, or 95.1 MT/yr (104.8 tons/yr).

The above oil analysis and the lubricants input to the 80 inch mill were used to develop the mass balance shown in Figure 5-2. The criteria information for the 80 inch cold strip mill is presented in Table 5-2.

5.3.2 56 INCH FOUR-STAND TANDEM COLD REDUCTION MILL

The basic operating parameters for the 56 inch four-stand cold reduction mill are depicted in Table 5-3.

5.3.2.1 Lubricant Use

Yearly lubricant use at the 56 inch cold mill were as follows (see Figure 5-3):

Roll coolant (Tallow)	41 MT	(45 ton)
Back up bearing oil	185 MT	(204 ton)
Gear oil	14 MT	(15 ton)
Work roll bearing grease	22 MT	(24 ton)
Total	261 MT	(288 ton)

Assuming 0.9 kg/l (7.5 lb/gal) for oils, the total oil, grease and hydraulic fluid input to the plant is 288,167 l/yr (76,125.7 gal/yr). This estimates an oil and grease consumption factor of 0.30 kg/MT of steel produced (0.61 lb/ton).

As in the 80 inch cold strip mill, the roll solution (emulsion) utilized by the 56 inch cold strip mill is recirculated through a system similar to that shown in Figure 2-7. This roll emulsion has an oil concentration of approximately 60 percent.

5.3.2.2 Discharges to Wastewater Treatment Facilities and Other Losses

The average oil concentration in the wastewater discharge to the plant treatment facility was estimated to be 500 mg/l. This concentration is relatively high since the emulsion used on the strip is recycled. Only a small portion of the emulsion (usually less than ten percent) is permitted to enter the wastewater treatment plant. This practice minimizes the need for make up oil and reduces the load on the wastewater treatment plant. The average wastewater flow rate was 378 l/min (100 gal/min). This flow does not include possible shock

Table 5-3. 56 INCH FOUR-STAND TANDEM COLD REDUCTION MILL OPERATING AND LUBRICANT PARAMETERS (INLAND STEEL - INDIANA HARBOR WORKS)

Production: 851,000 MT/yr (1,070,000 tons) (1978 year)

Density of Steel: 40.8 lb/sq.ft/1 inch (average)

Density of oils, greases or hydraulic fluids: 0.9 kg/liter (7.5 lb/gal) (Average)

Output products (90 percent carbon steel) thickness:

Maximum 0.236 cm (0.093 inch)
Minimum 0.033 cm (0.013 inch)
Average 0.135 cm (0.053 inch)

Total number of working days: 176 days (48 percent of 365 days)

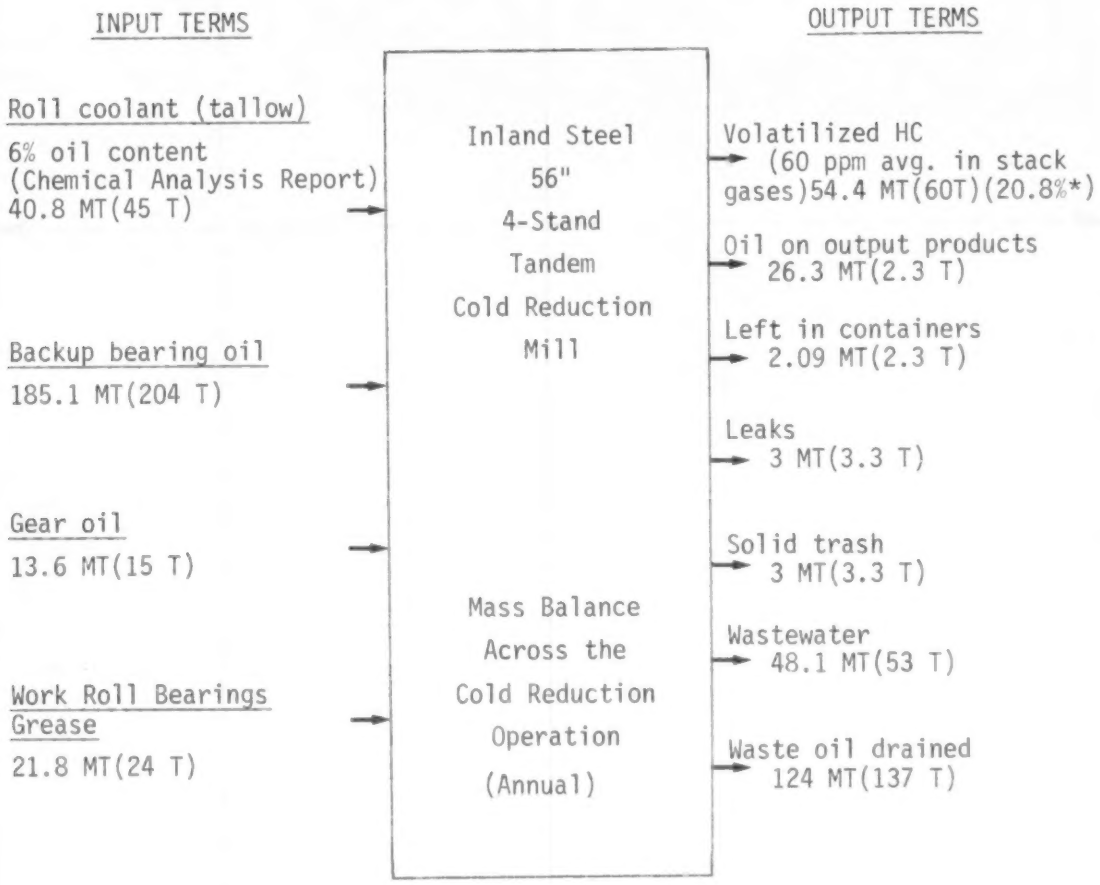
Resultant steel temperature: 66° to 121°C (150 - 250°F)

Cold reduction - No scale formation

Total lubricants (rolling oil, lubricant, grease and hydraulic fluid) required = 0.30 kg/MT (0.061 lb/ton)

Input oil/yr = 261 MT (288 tons)   Output oil = 261 MT (288 tons)

Figure 5-3. COLD STRIP MILL LUBRICATION MASS BALANCE


INPUT TERMS
OUTPUT TERMS
Roll coolant (tallow)
6% oil content
(Chemical Analysis Report)
40.8 MT(45 T)
Backup bearing oil
185.1 MT(204 T)
Gear oil
13.6 MT(15 T)
Work Roll Bearings Grease
21.8 MT(24 T)
Inland Steel
56"
4-Stand
Tandem
Cold Reduction
Mill
Mass Balance
Across the
Cold Reduction
Operation
(Annual)
Volatilized HC
(60 ppm avg. in stack gases)54.4 MT(60T)(20.8%*)
Oil on output products
26.3 MT(2.3 T)
Left in containers
2.09 MT(2.3 T)
Leaks
3 MT(3.3 T)
Solid trash
3 MT(3.3 T)
Wastewater
48.1 MT(53 T)
Waste oil drained
124 MT(137 T)

* Percent of total output.

loads to the treatment plant when the recycle system is drained and completely made up (approximately once per week). Incorporating these factors into the mass balance yields a total of 48 MT/yr (53 ton) of oil delivered to the wastewater treatment plant (18.4 percent).

The terms left in containers; leaks and spills on ground floors; and solid trash were estimated to be 0.8 percent, 1.1 percent, and 1.1 percent, respectively. These estimates were determined from data gathered from all the steel facilities involved in the project. It was assumed that these factors would remain essentially constant from mill to mill. The left in containers term was derived from the following two values:

0.5 percent of oil and hydraulic fluid input (purchase)
5 percent of grease input (purchase)

The left in container consumption factor is estimated to be 2.1 MT/yr (2.3 tons/yr). The leaks and spills on ground floor factors were determined to be 0.004 kg/MT of steel produced (0.007 lb/ton of steel). The last factor, solid trash and debris, was also determined to be 0.004 kg/MT of steel produced (0.007 lb/ton of steel). The estimates for this factor yield a consumption factor of 3.0 MT/yr. Due to the nature of these three terms, the degree of accuracy is probably low. With respect to the remaining loss terms, these factors are comparatively negligible.

5.3.2.3 Material Balance

The following estimation and generalizations were made for a 56 inch four-stand tandem cold reduction mill.

Volatilized Hydrocarbons:

Stack hydrocarbons sampling was conducted on the discharge duct for quantification of total hydrocarbons (expressed as methane) and further identification of hydrocarbon species. The average HC concentration was determined to be 60 ppm which results in 54 MT/yr (60 tons/yr) of emissions (see Section 4).

Oil on Output Products:

Data gathered at the Indiana Harbor Works indicated that 15 milligrams of oil remained on the strip as surface film on every square foot of steel. The average thickness of the resultant steel strip was determined to be 0.135 cm (0.05 inch). The actual steel production was 0.94 x 10^6 tons/yr (1977 figure) and the average steel density assumed was 40.8 lb/sq ft/1 inch thickness. From these data, oil loss on final output products was estimated to be 26 MT/yr (29 tons/yr).

Other loss terms include left in containers; leaks and spills; and trash and debris losses. These data were presented in the previous section. Waste oil drained and collected was estimated to account for the balance of the total loss or 124 MT/yr (137 tons/yr). The 56 inch cold strip mill operating parameters are presented in Table 5-3, and the lubricant material balance is presented in Figure 5-3.

5.3.3 80 INCH SIX FINISHING STAND HOT STRIP MILL

The basic process parameters for the 80 inch hot strip mill are outlined in Table 5-4. No emission testing was performed at this mill. All terms are derived from information received by PES from Inland Steel, and from estimations determined from data gathered on similar rolling operations.

5.3.3.1 Lubricant Use

Yearly lubricant usage at the 80 inch Six Finishing Stand Hot Strip Mill were as follows:

Inverted emulsion	3.1 MT	(3.8 tons)
Lubricating oils	1100 MT	(1220 tons)
Greases	299 MT	(330 tons)
Hydraulic fluid	8.5 MT	(9.4 tons)
Total	1420 MT	(1560 tons)

Table 5-4. 80 INCH SIX FINISHING STANDS HOT STRIP MILL OPERATING AND LUBRICANT PARAMETERS (INLAND STEEL, INDIANA HARBOR WORKS, EAST CHICAGO)

Production:

Design Capacity: 3.36×10^6 MT/yr (4.1×10^6 tons/yr)

Actual Production: 3,520,000 MT/yr (4,080,000 tons/yr)

Design Capacity (Nationwide avg.): 2.34×10^6 Metric tons/yr (2.58×10^6 tons/yr)

Density of steel products: 40.8 lb/sq ft/1 inch (avg)

Density of oil, hydraulic fluid or grease: 0.9 kg/liter (7.5 lb/gal) (avg)

Number of Finishing Stands: 6

Average concentration of hydrocarbon (as methane) emissions from Finishing Stands (with no application of rolling oils): 15 ppm

80" Hot Strip Rolling temperature (slab from furance): 1280-1430°C (2350-2600°F)

Hot reduction is accompanied by scale formation.

Working days = 909 turns 82 percent of 365 days

Overall lubricants requirement = 0.394 Kg/ton (0.805 lb/ton steel product.

Lubricant Input per year= 1410 MT (1560 tons)

Lubricant Output per year = 1410 MT (1560 tons)

Assuming a density of 0.9 kg/l (7.5 lb/gal) for oils, the total oil, grease and hydraulic fluid input to the plant is 1.572,900 l/yr (415,400 gal/yr). This yields an oil and grease consumption factor of 0.394 kg/MT of steel produced (0.805 lb/ton).

5.3.3.2 Discharges to Wastewater Treatment Facilities and Other Losses

The average oil concentration in the wastewater discharge to the plant treatment facility was estimated to be 18.4 ppm. This was estimated to be equal to the concentration of the roughing and finishing stand's effluent from the 84 inch (seven finishing stands) hot strip mill in U.S. Steel, Gary Works. This value is also consistent with the 20 ppm average determined by Patterson for hot rolling mills (Ref. 4). The average wastewater flow rate is 83,300 l/min (22,000 gal/min). Incorporating these factors into the mass balance yields a total 492 MT/yr (543 tons) of oil delivered to the wastewater treatment plant.

The terms left in containers; leaks and spills on ground/floor; and solid trash were estimated to be 1.45 percent, 0.88 percent, and 0.88 percent respectively. These estimates were derived from data gathered from all the steel facilities involved in the project. It was assumed that these factors would remain essentially constant from mill to mill. The left in containers term was derived from the following two values:

0.5 percent of oil and hydraulic fluid input (purchase)
5 percent of grease input (purchase)

Calculations from the above values yield a consumption factor of 20.5 MT/yr (22.6 tons/yr). The leaks and spills on ground floor was estimated to be 0.004 kg/MT of steel produced (0.007 lb/ton). These estimates lead to a consumption factor of 12.5 MT/yr (13.8 tons/yr) for leaks and spills, and 12.5 MT/yr (13.8 tons/yr) for solid trash and debris. Due to the nature of these three terms, the accuracy of these estimates is probably very poor.

5.3.3.3 Material Balance

Volatilized Hydrocarbons:

The hot reduction process in this hot strip mill does not use rolling oil. In absence of any available data, the average total hydrocarbon (as methane) concentration was estimated to be equal to the average level prevailing in the ambient air surrounding the seven finishing stands area of the U.S. Steel, Gary Works' 84 inch hot strip mill (with no use of rolling oil). An average concentration level of 15 ppm was monitored at U.S. Steel with a precalibrated portable organic vapor analyzer. Therefore, the volatilized hydrocarbon loss term is estimated to be 26.8 MT/yr (29.5 tons/yr) (see Section 4.2).

Oil on Output Products:

Oil on output products (left as surface oil film) is assumed to be negligible because of the high temperatures inherent in this process.

Oil on Scales:

During the hot reduction process, scale formed due to surface oxidation was estimated to be 2.26 percent of the steel produced and contained 0.1335 percent of oil on the scales surfaces. From these two factors, the oil lost on scale was estimated to be 105 MT/yr (116 ton per year).

Sludge Disposal:

Sludge formation from oxidation and wastewater treatment was estimated to be 1.88 percent of strip production and contained 0.625 percent oil. Using these two factors, the oil lost to sludges was estimated to be 413 MT/yr (455 ton per year).

Waste oil drained and collected was estimated as the balance of the total loss or 333 MT/yr (367 ton/yr). The mass balance calculated from the above analysis along with other information including the 80 inch mill's lubricant inputs are presented in Figure 5-4. Operating parameters of the hot strip mill are presented in Table 5-4.

5.4 U.S. STEEL, GARY WORKS, INDIANA

A summary of the major rolling mills and products associated with the U.S. Steel, Gary Works is presented in Table 5-5. The information presented in the table is a summary of data provided in the AISI Directory of Iron and Steel Works. The actual production during the period for which lubrication usage data were reported was approximately 64 percent of the plant's rated capacity of 7.26×10^9 kg/yr (8.0×10^6 tons/yr) or 4.63×10^9 kg/yr (5.1×10^6 tons/yr).

Mass balances were performed for three mills at this facility: the 80 inch five-stand tandem cold reduction mill; the 84 inch seven finishing stand hot strip mill (with no rolling oil used); and the 84 inch seven finishing hot strip mill (with rolling oil used). The 84 inch seven finishing stand hot strip mill (with no rolling oil used) was monitored to determine actual volatilized hydrocarbons generated into the surrounding air by the hot rolling operation.

5.4.1 80 INCH FIVE-STAND TANDEM COLD REDUCTION MILL

The basic process parameters for the 80 inch mill are outlined in Table 5-6.

5.4.1.1 Lubricant Usage

The yearly lubricant usage at the 80 inch five-stand tandem cold reduction mill were determined to be:

Table 5-5. UNITED STATES STEEL CORPORATION - GARY, INDIANA*

No.	Type of Mill	Annual Rolling Capacity	
1	Slab	2,820,000	5,211,000 Net Tons
1	Billet	1,200,000	
2	Blooming	1,191,000	
1	Rail	682,000	15,557,800 Net Tons
1	Plate	574,000	
9	Bar	2,083,000	
2	Hot strip	6,010,000	
3	Sheet - Cold roll	1,314,800	
5	Sheet temper	2,365,900	
3	Tin - Cold roll	1,547,400	
3	Tin temper	980,700	
31		20,768,800 NET TONS	

---

* Equipment and annual rolling capacity data from AISI Directory of Iron and Steel Works (1.0 ton = 907.2 kg).

Roll coolant	547 MT	(603 tons)
Lubricating oil	558 MT	(615 tons)
Greases	4.5 MT	(5 tons)
Hydraulic fluid	467 MT	(575 tons)
Total	1,577 MT	(1,798 tons)

Assuming a density of 0.9 kg/l (7.5 lb/gal) for oils, the total oil, grease and hydraulic fluid input to the plant is 1,751,600 l/yr (462,600 gal/yr). Calculations from these values yield an oil and grease consumption factor of 1.83 kg/MT of steel product (3.67 lb/ton).

5.4.1.2 Discharges to Wastewater Treatment Facilities and Other Losses

In the absence of mill specific data, the percent of total lubricant input lost through the wastewater discharge to treatment facility for this mill was estimated to be 12.6 percent. This is an arithmetic average of the percent of total lubricants input lost through wastewater discharge to treatment facility for the 56 inch four-stand (18.4 percent), and the 80 inch five-stand (8.8 percent) cold strip mills in Inland Steel's, Indiana Harbor Works. Incorporating this estimation into the analysis yields 214.4 MT/yr (236.3 tons/year).

The terms left in containers; leaks and spills on ground floor; and solid trash were estimated to be 0.7 percent, 1.7 percent, and 1.7 percent respectively. These estimates were determined from data gathered from all the steel facilities involved in the project. It was assumed that these factors would remain essentially constant from mill to mill. The left in containers term was derived from the following two values:

0.5 percent of oil and hydraulic fluid input (purchase)
5 percent of grease input (purchase)

These values were taken from U.S. Steel, Gary Works' data. Calculations from these estimates yield a consumption factor of 11.1 MT/yr

(12.1 tons/yr). The leaks and spills on ground floor term was estimated from Gary Works' data to be 0.004 kg/MT of steel produced (0.007 lb/ton of steel). The last factor, solid trash and debris was calculated to be 0.004 kg/MT of steel produced (0.007 lb/ton of steel). These estimates result in a consumption factor of 26.8 MT/yr (29.5 ton/yr) for leaks and spills; and 26.8 MT/yr (29.5 ton/yr) for solid trash and debris. Due to the nature of these three terms, the accuracy is probably low. However, with respect to other loss terms, these losses are comparatively negligible.

5.4.1.3 Material Loss

Estimates and generalizations have been made by PES for the 80 inch five-stand tandem cold reduction mill. The results are presented below.

Volatilized Hydrocarbons:

Stack hydrocarbon sampling was not conducted for volatilized hydrocarbons. In absence of this data the average hydrocarbon emission level was assumed to be 60 ppm, which corresponds to the concentration found at Inland Steels', Indiana Harbor Works' 80 inch five-stand cold strip mill. Using this concentration, the volatilized hydrocarbon loss is 23.9 percent of total lubricants input, or 377 MT/yr (415 ton/yr).

Oil on Output Products:

The percentage of total lubricant input leaving on steel products was estimated to be 12.6 percent. This is the average value for Inland Steel, Indiana Harbor Works' 56 inch cold stip mill and the 80 inch cold strip mill (data from Inland Steel indicated 15 milligrams oil loss per square foot of output steel products). Utilizing this factor, the oil on product loss term was calculated to be 199 MT/yr (219 ton/yr).

Waste oil drained and collected was estimated to be the balance of the total loss, or 722 MT/yr (796 ton/yr).

The above analysis resulted in the mass balance illustrated in Figure 5-5. All necessary operating parameters from the 80 inch mill are presented in Table 5-6.

5.4.2 84 INCH SEVEN-STAND HOT STRIP MILL (With No Application of Rolling Oils

Table 5-7 outlines the basic parameters for the 84-inch mill while no rolling oils are being applied to the strip. This was the situation encountered during the sampling program (see Section 4.2).

5.4.2.1 Lubricant Use

Yearly lubricant use at the 84 inch seven-stand hot strip mill (with no rolling oil) were estimated to be:

Lubricating oils	2280 MT	(2517 tons)
Greases	272 MT	(300 tons)
Hydraulic fluids	33.4 MT	(37 tons)
Total	2590 MT	(2854 tons)

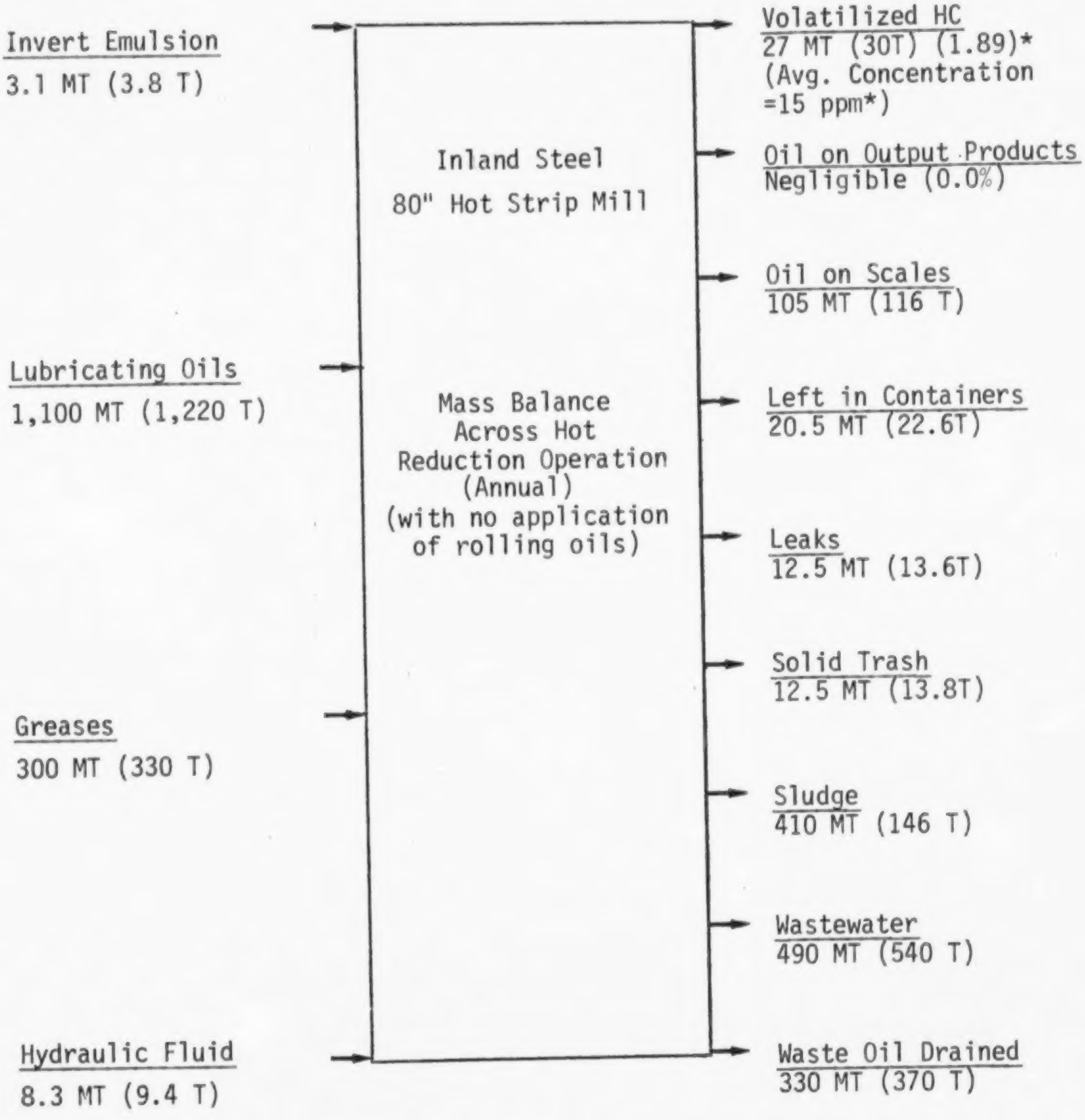
Assuming a density of 0.9 kg/l (7.5 lb/gal) for oils, the total oil, grease and hydraulic fluid input to the plant is 2,880,000 l/yr (760,000 gal/yr). The oil and grease consumption factor is therefore 0.988 kg/MT of steel produced (2.02 lb/ton).

5.4.2.2 Discharges to Wastewater Treatment Facilities and Other Losses

An estimated 302 MT/yr (333 tons/yr) of oil is lost through the mills wastewater discharge system. This data was calculated and presented to PES by U.S. Steel engineers.

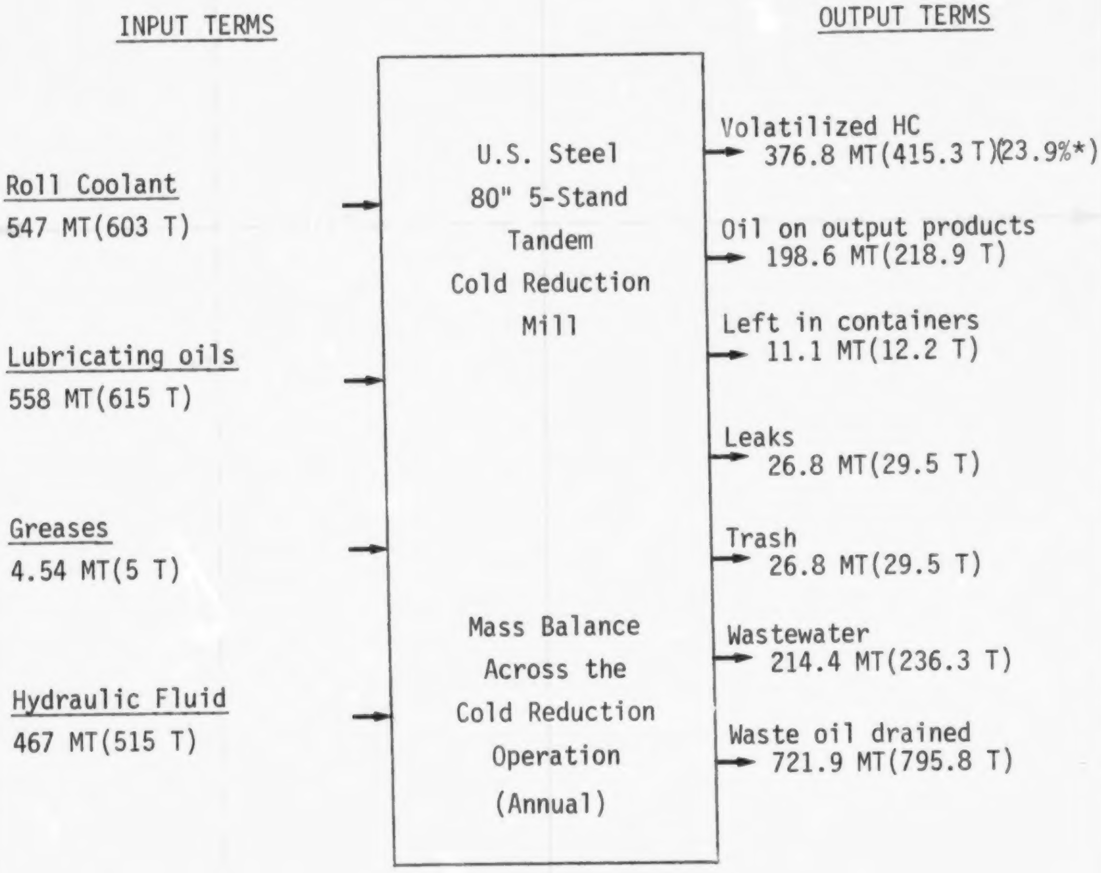
The terms left in containers; leaks and spills on ground floor; and solid trash were estimated to be 1.1 percent, 0.4 percent, and 0.4 percent respectively. These estimates were determined from data gathered from all the steel facilities involved in the project.

Figure 5-4. 80 INCH HOT STRIP MILL NOT UTILIZING ROLLING OILS


Invert Emulsion
3.1 MT (3.8 T)
Lubricating Oils
1,100 MT (1,220 T)
Greases
300 MT (330 T)
Hydraulic Fluid
8.3 MT (9.4 T)
Inland Steel
80" Hot Strip Mill
Mass Balance
Across Hot
Reduction Operation
(Annual)
(with no application
of rolling oils)
Volatilized HC
27 MT (30T) (1.89)*
(Avg. Concentration
=15 ppm*)
Oil on Output Products
Negligible (0.0%)
Oil on Scales
105 MT (116 T)
Left in Containers
20.5 MT (22.6T)
Leaks
12.5 MT (13.6T)
Solid Trash
12.5 MT (13.8T)
Sludge
410 MT (146 T)
Wastewater
490 MT (540 T)
Waste Oil Drained
330 MT (370 T)

* Percent total output.

Figure 5-5. COLD STRIP MILL LUBRICATION MASS BALANCE


INPUT TERMS
OUTPUT TERMS
Roll Coolant
547 MT(603 T)
Lubricating oils
558 MT(615 T)
Greases
4.54 MT(5 T)
Hydraulic Fluid
467 MT(515 T)
U.S. Steel
80" 5-Stand
Tandem
Cold Reduction
Mill
Mass Balance
Across the
Cold Reduction
Operation
(Annual)
Volatilized HC
376.8 MT(415.3 T)(23.9%*)
Oil on output products
198.6 MT(218.9 T)
Left in containers
11.1 MT(12.2 T)
Leaks
26.8 MT(29.5 T)
Trash
26.8 MT(29.5 T)
Wastewater
214.4 MT(236.3 T)
Waste oil drained
721.9 MT(795.8 T)

* Percent of total output.

Table 5-6. 80 INCH FIVE-STAND COLD REDUCTION MILL OPERATING AND LUBRICANT PARAMETERS (U.S. STEEL - GARY WORKS)

Production:

Annual rolling capacity: 1.44×10^{6} MT/yr
(1.59×10^{6} tons/yr)

Actual production: 60% design capacity
= $0.8.62 \times 10^{6}$ MT/yr (0.95×10^{6} tons/yr)

Design capacity (Nationwide avg): 1.18×10^{6} MT/yr
(1.3×10^{6} tons/yr)

Design of steel: 40.8 lb/sq. ft. 1/inch (avg)

Design of oil grease or hydraulic fluid: 0.9 kg/l (7.512 lb/gal)
(avg)

Total number of working days: 60 percent of 365 days

Resultant steel temperature: 66^{o}C-127^{o}C (150^{o}F-260^{F})

Cold reduction: No scale formation

Total lubricants (Rolling oil, lubricant, grease and hydraulic fluid) required = 1.829 kg/MT steel product
(3.658 lb/ton)

Input = 1576.4 MT
(1737.6 tons)

Output = 1576.4 MT
(1737.6 tons)

Table 5-7. 84 INCH (SEVEN FINISHING STANDS) HOT STRIP MILL OPERATING AND LUBRICANT PARAMETERS (WITH NO APPLICATION OF ROLLING OILS) (U.S. STEEL - GARY WORKS)

Production:

Design capacity: 4.01×10^6 MT/yr (4.42×10^6 tons/yr)
(AISI data)

Actual production: 64% design capacity
= 2.571×10^6 MT/hr (2.83×10^6 tons/yr)

Design capacity (Nationwide avg): 2.34×10^6 MT/yr
(2.58×10^6 tons/yr)

Density of steel products: 40.8 lb/sq.ft/1 inch (avg)

Density of oils, hydraulic fluid or grease: 0.9 kg/liter
(7.5 lb/gal)(avg)

Output product width: (after Finishing Stands)
Minimum: 45.7 cm (18 inch)
Maximum: 194 cm (76.5 inch)
Average: 120 cm (47.3 inch)

Number of Finishing Stands: 7

Avg. distance between two consecutive Finishing Stands: 5.5 m (18 ft)

Finishing Stand (Work rolls)	Average strip travel speed m/sec	ft/sec
No. 1	1.62	(5.3)
2	2.54	(8.33)
3	3.64	(11.9)
4	4.73	(15.5)
5	4.73	(15.5)
6	7.58	(24.9)
7	7.58	(24.9)

84 in. Hot Strip Rolling temperature (slab from furnace):
1290 - 1430°C (2350 - 2600°F)

Hot reduction is accompanied with scale formation.

Total number of working days: 234 days (64% of 365 days)

Average concentration of hydrocarbon (as methane) emissions from Finishing Stands (with no application of rolling oils:
15 ppm (avg) (Century OVA-108 continuous HC monitor)

Overall lubricants requirements: 0.988 kg/MT
(2.02 lb/ton steel product)

Input = 2590 MT (2850 tons) Output = 2590 MT (2850 tons)

The left in containers term was derived from the following two values:

0.5 percent of oil and hydraulic fluid input (purchase)
5 percent of grease input (purchase)

These values were from U.S. Steel, Gary Works' data. This estimate was used to calculate a consumption factor of 29 MT/yr (32 ton/yr). The leaks and spills on ground floor loss term was estimated to be 0.004 kg/MT of steel produced (0.006 lb/ton of steel). The last factor, solid trash and debris was also determined to be 0.004 kg/MT of steel produced (0.007 lb/ton of steel). A consumption factor of 9.07 MT/yr (10 tons/yr) for solid trash and debris was calculated from these estimated values.

5.4.2.3 Material Balance

Volatilized Hydrocarbons:

The hot reduction process in this hot strip mill does not use rolling oil. The average total hydrocarbon (as methane) concentration surrounding the seven finishing stands area was 15 ppm. Using this concentration, the volatilized hydrocarbon loss term is 42.6 MT/yr (47 tons/year) emission (see Section 4.2 for actual sampling calculations).

Oil on Output Products:

The temperatures of hot reduction are much higher than the fire point of lubricants used in the mill stands, therefore oil remaining on product is considered to be negligible.

Oil on Scales:

Scale formation from surface oxidation was estimated to be 3.53 percent of the steel strip produced. The scale sampled at the wastewater flame outlet contained 0.53 percent of oil on its surfaces. Oil loss on scale was determined to be 481 MT/yr (530 ton/yr).

Sludge Disposal:

Sludge formation was estimated to be 1.88 percent of the steel strip produced. It was estimated to contain 2.5 percent of oil. Using these two factors, the oil loss from sludges was estimated to be 1210 MT/yr (1330 ton/yr).

Waste oil drained and collected was estimated to constitute the balance of the oil loss, or 508 MT/yr (560 ton/yr).

The above analysis was used to produce the mass balance in Figure 5-6. The basic process parameters for the 84 inch hot strip mill are presented in Table 5-7.

5.4.3 84 INCH SEVEN-STAND HOT STRIP MILL (With Application of Rolling Oils)

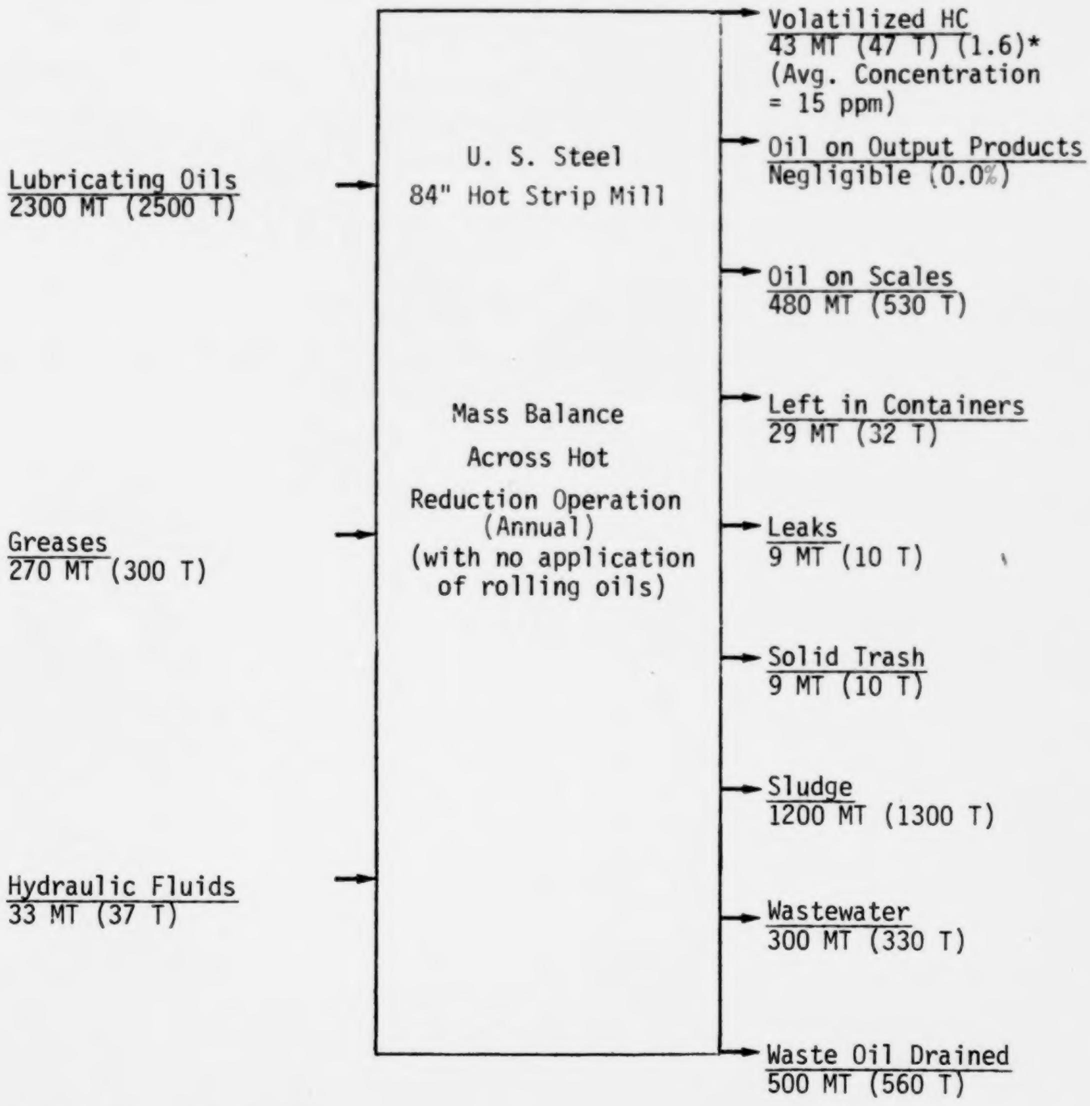
The basic process parameters for the 84 inch mill while using rolling oils are found in Table 5-8.

5.4.3.1 Lubricant Use

Yearly lubricant use at the 84 inch seven stand hot strip mill which used rolling oils were as follows:

Rolling Oils	729 MT	(804 tons)
Lubricating Oils	2280 MT	(2520 tons)
Greases	272 MT	(300 tons)
Hydraulic fluids	33.4 MT	(36.8 tons)
Total	3320 MT	(3660 tons)

Figure 5-6. 84 INCH HOT STRIP MILL NOT UTILIZING ROLLING OILS


Lubricating Oils
2300 MT (2500 T)
Greases
270 MT (300 T)
Hydraulic Fluids
33 MT (37 T)
U. S. Steel
84" Hot Strip Mill
Mass Balance
Across Hot
Reduction Operation
(Annual)
(with no application
of rolling oils)
Volatilized HC
43 MT (47 T) (1.6)*
(Avg. Concentration
= 15 ppm)
Oil on Output Products
Negligible (0.0%)
Oil on Scales
480 MT (530 T)
Left in Containers
29 MT (32 T)
Leaks
9 MT (10 T)
Solid Trash
9 MT (10 T)
Sludge
1200 MT (1300 T)
Wastewater
300 MT (330 T)
Waste Oil Drained
500 MT (560 T)

* Percent total output.

Table 5-8. 84 INCH (SEVEN FINISHING STANDS) HOT STRIP MILL OPERATING AND LUBRICANT PARAMETERS (WITH APPLICATION OF ROLLING OILS) (U.S. STEEL - GARY WORKS)

Production:

Design capacity: 4.01 x 10^6 MT/yr (4.42 x 10^6 tons/yr)
(AISI data)

Actual production: 64% design capacity
= 2.57 x 10^6 MT/hr (2.83 x 10^6 tons/yr)

Design capacity (Nationwide avg): 2.34 x 10^6 MT/yr
(2.58 x 10^6 tons/yr)

Density of steel products: 40.8 lb/sq.ft/1 inch (avg)

Density of oils, hydraulic fluid or grease: 0.9 kg/liter
(7.5 lb/gal)(avg)

Output product width: (after Finishing Stands)
Minimum: 45.72 cm (18 inch)
Maximum: 194 cm (76.5 inch)
Average: 120 cm (47.3 inch)

Number of Finishing Stands: 7

Avg. distance between two consecutive Finishing Stands: 5.5 m (18 ft)

Finishing Stand (Work rolls)	Average strip travel speed	
	m/sec	ft/sec
No. 1	1.62	(5.3)
2	2.54	(8.33)
3	3.64	(11.9)
4	4.73	(15.5)
5	4.73	(15.5)
6	7.58	(24.9)
7	7.58	(24.9)

84 in. Hot Strip Rolling temperature (slab from furnace):
1290 - 1430°C (2350 - 2600°F)

Hot reduction is accompanied with scale formation.

Total number of working days: 234 days (64% of 365 days)

Average concentration of hydrocarbon (as methane) emissions from Finishing Stands (with application of rolling oils: 60-75 ppm

Overall lubricants requirements: 1.27 kg/MT
(2.59 lb/ton steel product)

Input = 3320 MT (3660 tons) Output = 3320 MT (3660 tons)

Assuming 0.9 kg/l for oils, the total oil, grease, and hydraulic fluid input to the plant is 3,690,000 l/yr (974,000 gals/yr). This yields an oil and grease consumption factor of 1.27 kg/MT of steel product (2.59 lb/ton).

5.4.3.2 Discharges to Wastewater Treatment Facilities and Other Losses

302 MT/yr (332.9 tons/yr) of oil is estimated to be lost through the mills wastewater discharge. This quantity is assumed to be the same as that estimated for the same mill not using rolling oils. No accurate wastewater information was available for the mill while using rolling oils.

The terms left in containers; leaks and spills on ground floor; and solid trash were estimated to be 0.9 percent, 0.3 percent, and 0.3 percent respectively. The left in containers term was derived from the following two values:

0.5 percent of oil and hydraulic fluid input (purchase)
5 percent of grease input (purchase)

These values were obtained from U.S. Steel, Gary Works' data . A consumption factor of 29 MT/yr (32 ton/yr) was calculated based on these values. The leaks and spills on ground floor term was estimated to be 0.004 kg/MT of steel produced (0.007 lb/ton of steel). The last factor of solid trash and debris was also determined to be 0.004 kg/MT of steel produced (0.007 lb/ton of steel). From these estimates, a consumption factor of 9.1 MT/yr (10 tons/yr) for solid trash and debris was derived.

5.4.3.3 Material Balance

Sampling was not performed on the hot strip mill using rolling oils. The oil loss terms have been estimated from interpolating data gathered from sampling a conventional hot strip mill which does not utilize rolling solutions. The volatilization term has been determined by the following method:

Volatilized Hydrocarbons:

The hot reduction process in this hot strip mill uses rolling oil. The average total hydrocarbon (as methane) concentration at the finishing stands level was estimated to be 75 ppm. It was assumed that applying rolling oil increases the concentration by 60 ppm, the equivalent level emitted in cold strip rolling. Furthermore, the HC emission concentration level from a hot strip mill using rolling oil is assumed to be equivalent to the concentration from a cold strip mill using rolling oil and a hot strip mill with no application of rolling oil. Incorporating these factors, the volatilized hydro- carbon loss term becomes 214 MT/year (236 ton/yr).

Carbonized:

Carbonization is defined as the conversion of organic matter to the carbonic form due to the combination of an insufficient oxygen supply, high temperature, and high pressure. It was estimated that 30 percent of the rolling oil was carbonized to graphitic form, resulting in a solid lubricant film on work rolls. This estimate was used to calculate the 218.8 MT/yr (241.2 tons/yr) emission level (6.6 percent of total lubricants input).

Scrap Loss:

A small amount, estimated at 2.2 percent of rolling oil used during the hot reduction rolling operation, remains on the steel scrap. This loss accounts for 16.3 MT/yr (18 tons/yr) of oil.

Combusted:

The temperatures in hot reduction rolling are much higher than the lubricant's fire points. Therefore, it is estimated that a significant loss of the total rolling oil is due to combustion. The rolling oil loss avenues are: volatilization, carbonization, scrap loss, and combustion. Using this analysis, it is estimated that 323 MT/yr (356 tons/yr) rolling oil is lost through combustion (44.3 percent of rolling oil).

Oil on Output Products:

The oil remaining on output products is estimated to be negligible, due to the temperatures encountered.

Oil on Scales

During the hot reduction process, scale formation due to surface oxidation was estimated to be 3.5 percent of steel strip produced and contained 0.53 percent of oil on its surfaces. From these surfaces, the oil loss on scale was estimated to be 48 MT/yr (53 ton/yr).

Sludge Disposal:

Sludge formation was estimated to be 1.9 percent of steel strip produced and these sludges contained 2.5 percent of oil. The oil loss on sludges was estimated to be 1209 MT/yr (1330 ton/yr). Waste oil drained and collected was estimated as the balance of the total loss, or 508 MT/yr (560 ton/yr).

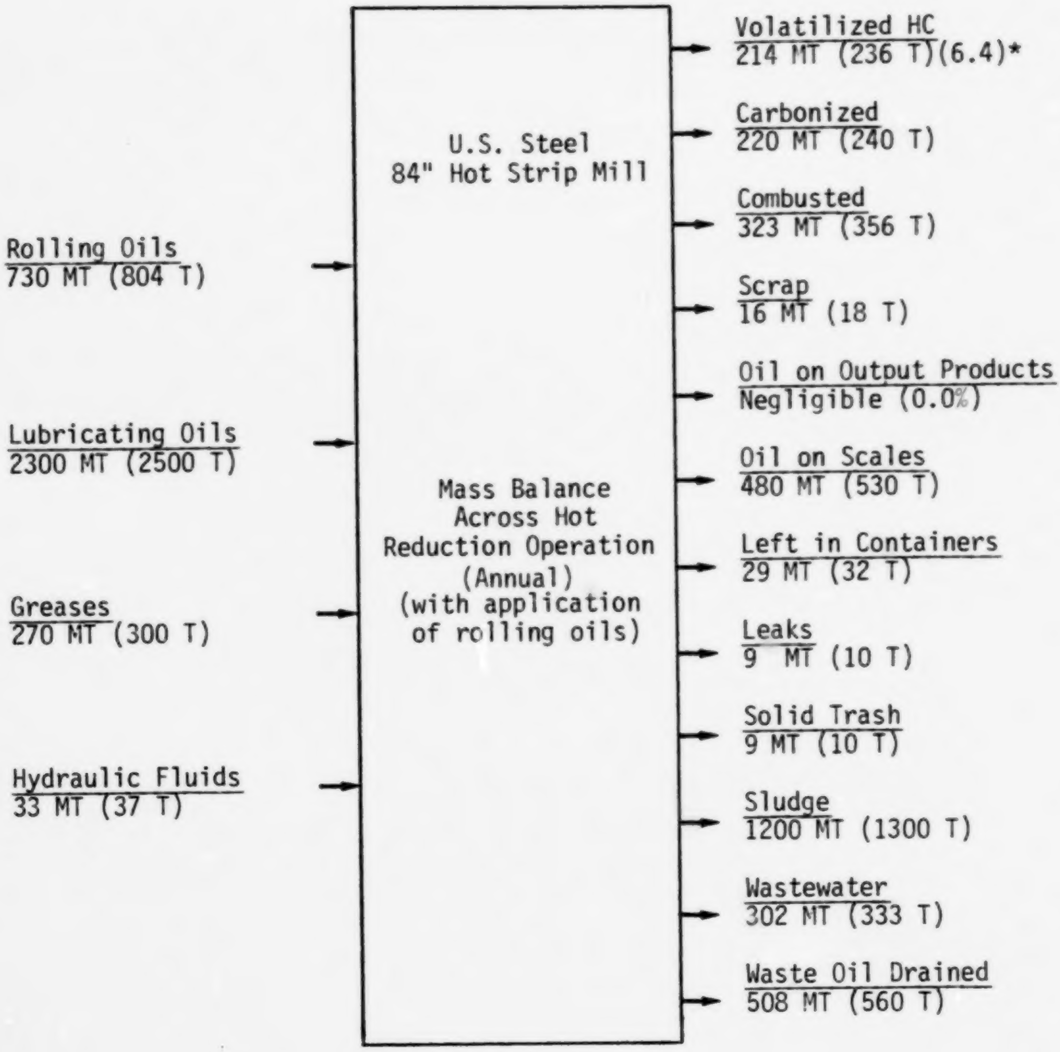
The mass balance for the 84 inch hot strip mill while using rolling oils is presented in Figure 5-7. The mills operating parameters are presented in Table 5-8.

5.5 NATIONAL STEEL, ECORSE WORKS AT DETROIT

A summary of the major rolling mills and products associated with the National Steel, Ecorse Works is presented in Table 5-9. This information is a summary of data from the AISI Directory of Iron and Steel Works. Actual production during the period for which lubrication usage data were reported was approximately 78 percent of the plant's cold and hot strip mill's rated capacity of 7.3×10^6 MT/yr (8×10^6 tons/yr) or 5.7×10^6 MT/yr (6.3×10^6 tons/yr).

Mass balances were performed for the 80 and 93 inch cold reduction mills and the 80 inch hot strip mill which used rolling oils. Stack or ambient hydrocarbon monitoring was not conducted at this facility.

Figure 5-7. 84 INCH HOT STRIP MILL UTILIZING ROLLING OILS


U.S. Steel
84" Hot Strip Mill
Mass Balance Across Hot Reduction Operation (Annual) (with application of rolling oils)
Rolling Oils 730 MT (804 T)
Lubricating Oils 2300 MT (2500 T)
Greases 270 MT (300 T)
Hydraulic Fluids 33 MT (37 T)
Volatilized HC 214 MT (236 T)(6.4)*
Carbonized 220 MT (240 T)
Combusted 323 MT (356 T)
Scrap 16 MT (18 T)
Oil on Output Products Negligible (0.0%)
Oil on Scales 480 MT (530 T)
Left in Containers 29 MT (32 T)
Leaks 9 MT (10 T)
Solid Trash 9 MT (10 T)
Sludge 1200 MT (1300 T)
Wastewater 302 MT (333 T)
Waste Oil Drained 508 MT (560 T)

* Percent of total output.

Table 5-9. NATIONAL STEEL CORPORATION*, WORKS AT ECORSE, DETROIT, MICHIGAN

No.	Type of Mill	Annual Rolling Capacity	
1	Slabbing	3,300,000	4,800,000 Net Tons
1	Blooming	1,500,000	
1	80" Hot Strip (cont.)	4,400,000	4,652,000 Net Tons
1	Sheet H.R. (skin pass)	250,000	
1	Sheet H.R. (skin pass)	187,000	
1	Strip Cont. H.R. (skin pass)	540,000	
1	Strip Cont.(cold red.)	675,000	
1	Strip Cont.(cold red.)	1,500,000	
3	Strip Cont. C.R. (skin pass)	1,500,000	
11		9,052,000	NET TONS

*Equipment and annual rolling capacity data from AISI Directory of Iron and Steel Works

(1.0 ton = 907.2 kg)

5.5.1 THE 80 INCH AND 93 INCH COLD REDUCTION MILLS AREA

The basic process parameters for the cold reduction mills area are presented in Table 5-10. A simplified flow diagram of the 80 inch air evacuation system is presented in Figure 5-8. Since individual lubricant data was not available for the 80 and 93 inch mills, all calculations consider the two mills as one unit.

5.5.1.1 Lubricant Usage

Yearly lubricant use at the cold reduction mills area was:

Roll coolant	425 MT	(469 tons)
Lubricating oils	458 MT	(505 tons)
Greases	8.26 MT	(9.1 tons)
Hydraulic fluids	782 MT	(862 tons)
Total	1680 MT	(1840 tons)

Assuming 0.9 kg/l (7.5 lb/gal) for oils, the total oil, grease and hydraulic fluid input to the plant is 1,870,000 l/yr (491,000 gals/yr). This yields an oil and grease consumption factor of 0.69 kg/MT of steel product (1.4 lb/ton steel).

5.5.1.2 Discharges to Wastewater Treatment Facilities and Other Losses

In absence of mill specific data, the percent of total lubricant input lost through wastewater discharge to the treatment facility was estimated to be 13.6 percent. This is an arithmetic average of the total lubricant input lost through wastewater discharge to treatment facility for the 56 inch four-stand (18.4 percent), and the 80 inch five-stand (8.8 percent) cold strip mills at the Inland Steel, Indiana Harbor Works. Discharge is estimated to be 228 MT/yr (251 tons/year).

Table 5-10. 80 INCH AND 93 INCH TANDEM MILLS COLD STRIP REDUCTION AREA OPERATING AND LUBRICANT PARAMETERS (NATIONAL STEEL, ECORSE WORKS, DETROIT, MICHIGAN)

Production: Annual Rolling Capacity: 3.33×10^6 MT/yr
(3.68×10^6 tons/yr)

Annual production (1977): 2.39×10^6 MT/yr
(2.63×10^6 tons/year)

Density of steel: 40.8 lb/sq.ft/1 inch (avg.)

Density of oil, grease or hydraulic fluid (avg.): 0.9 kg/liter
(7.5 lb/gal)

Total number of working days: 72% of 365 days

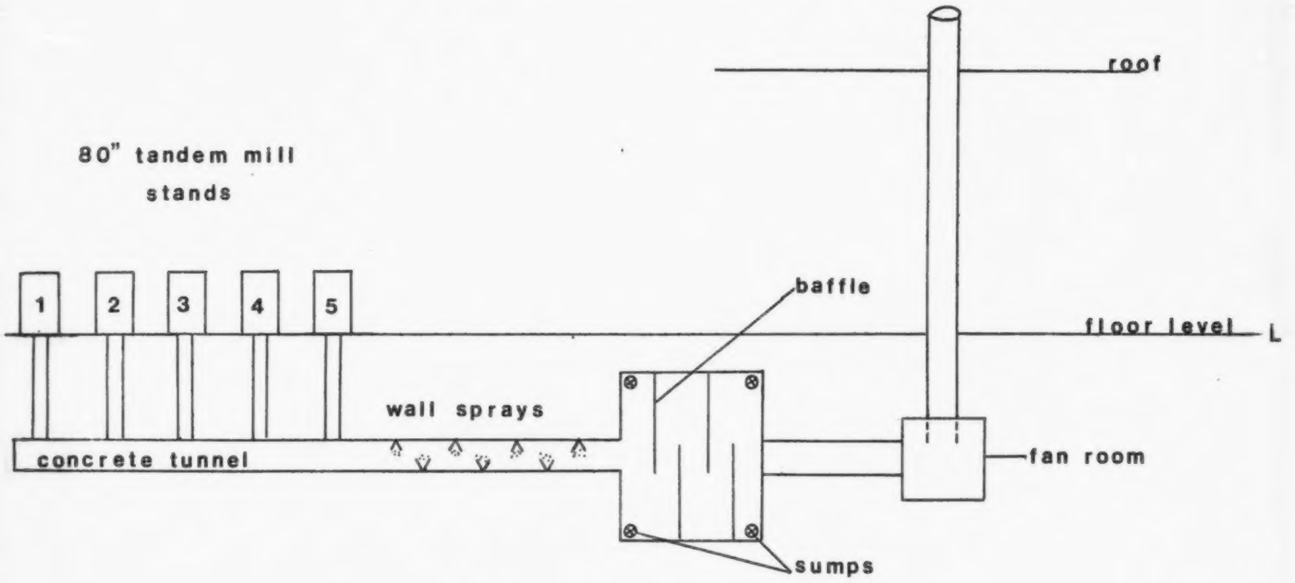
Resultant steel temperature: $66^0 - 121^0$C ($150 - 250^0$F)

Cold reduction - No scale formation

Total lubricants (rolling oil, lubricant, grease and hydraulic fluid) required = 0.686 kg/MT steel (1.40 lb/ton steel)

Input = 1680 MT (1,840 tons)   Output = 1670 MT (1,840 tons)

Figure 5-8. NATIONAL STEEL GREAT LAKES DIVISION 80 INCH FIVE-STAND TANDEM COLD MILL


80" tandem mill
stands
1
2
3
4
5
concrete tunnel
wall sprays
baffle
sumps
roof
floor level
L
fan room

The terms left in containers; leaks and spills on ground floor; and solid trash were estimated to be 0.7 percent, 1.7 percent, and 1.7 percent respectively. These estimates were developed from data gathered from all the steel facilities involved in the project. It was assumed that these factors would remain essentially constant from mill to mill. The left in containers term was derived from the following two values:

0.5 percent of oil and hydraulic fluid input (purchase)
5 percent of grease input (purchase)

These values were derived from U.S. Steel, Gary Works' data. A consumption factor of 11.7 MT/yr (12.9 tons/yr) was calculated from those values. A consumption factor of 28.5 MT/yr (31.4 tons/yr) was estimated for leaks and spills on ground floor, and solid trash and debris. Due to the nature of these three terms, accuracy is probably poor. However, this amount is a small portion of the total loss.

5.5.1.3 Material Balance

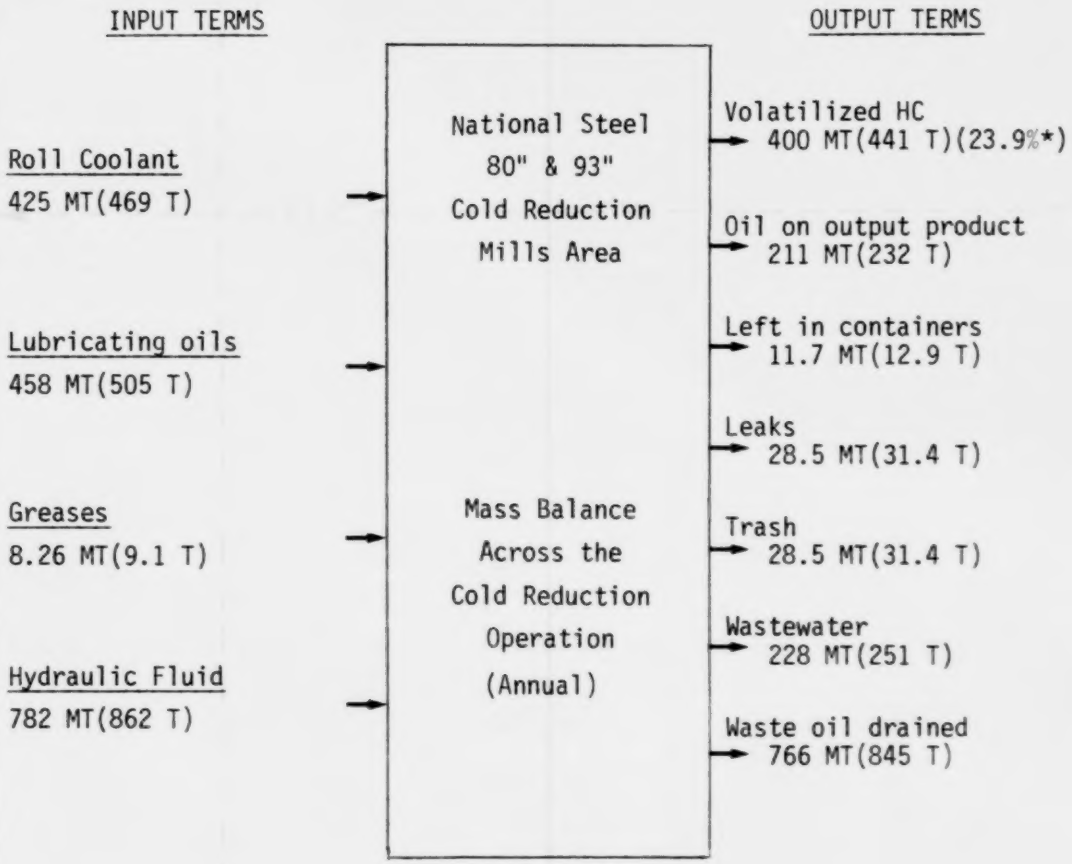
Volatilized Hydrocarbons:

Sampling was not conducted for volatilized hydrocarbons at the National Steel, Ecorse Plant. An average hydrocarbon emission level of 60 ppm was assumed (Inland Steel test result). Using this factor, the volatilized hydrocarbon loss term becomes 23.9 percent of total lubricant input, or 440.8 tons/yr.

Oil on Output Products:

The total lubricant input leaving on steel products was estimated to be 12.6 percent, which is the average value for Inland Steel, Indiana Harbor Works' 56 inch cold strip and 80 inch cold strip mills. This extrapolates to an oil loss factor of 211 MT/yr (232 tons/yr).

Figure 5-9. COLD STRIP MILL LUBRICATION MASS BALANCE


INPUT TERMS
OUTPUT TERMS
Roll Coolant
425 MT(469 T)
Lubricating oils
458 MT(505 T)
Greases
8.26 MT(9.1 T)
Hydraulic Fluid
782 MT(862 T)
National Steel
80" & 93"
Cold Reduction
Mills Area
Mass Balance
Across the
Cold Reduction
Operation
(Annual)
Volatilized HC
400 MT(441 T)(23.9%*)
Oil on output product
211 MT(232 T)
Left in containers
11.7 MT(12.9 T)
Leaks
28.5 MT(31.4 T)
Trash
28.5 MT(31.4 T)
Wastewater
228 MT(251 T)
Waste oil drained
766 MT(845 T)

* Percent of total output.

Waste oil drained and collected was estimated to be the balance of the total loss, or 767 MT/yr (845 ton/yr).

The above analysis was the basis for the oil mass balance shown in Figure 5-9.

5.5.2 80 INCH SEVEN FINISHING STAND HOT STRIP MILL

The basic process parameters for the 80 inch hot strip mill (with use of rolling oils) are presented in Table 5-11. This mill uses rolling oils for specific products, but no information was available on the percent of time that rolling oils are used.

5.5.2.1 Lubricant Use

Yearly lubricant use at the 80 inch seven finishing stand hot strip mill was:

Rolling Oils	596 MT	(657 ton)
Lubricating oils	535 MT	(590 ton)
Greases	75 MT	(83 ton)
Total	1206 MT	(1330 ton)

Assuming 0.9 kg/l (7.5 lb/gal) for oils, the total oil, grease, and hydraulic fluid input to the plant is 1,650,000 l/yr (435,000 gal/yr). Therefore, the oil and grease consumption factor is calculated to be 0.26 kg/MT of steel product (0.53 lb/ton).

5.5.2.2 Discharges to Wastewater Treatment Facilities and Other Losses

98.5 MT/yr (108.6 tons/yr) of oil is lost through wastewater discharge to the plant's treatment facility.

The terms left in containers: leaks and spills on ground floor; and solid trash were estimated to be 0.5 percent, 0.8 percent, and 0.8 percent resepectively. The left in containers term was derived from the following U.S. Steel values:

0.5 percent of oil and hydraulic fluid input (purchase)

5 percent of grease input (purchase)

Table 5-11. 80 INCH (SEVEN FINISHING STANDS) HOT STRIP MILL OPERATING AND LUBRICANT PARAMETERS (NATIONAL STEEL, ECORSE, DETROIT, MICHIGAN)

Production:

Design Capacity: 4.0 x 10^6 MT/yr (4.4 x 10^6 tons/yr) (AISI data)

Actual production: 3.35 x 10^6 MT/yr (3.693 x 10^6 tons/yr)

Design capacity (Nationwide avg): 2.34 x 10^6 MT/yr (2.58 x 10^6 tons/yr)

Density of steel products: (40.8 lb/sq.ft/1 inch (avg))

Density of oil, hydraulic fluid or grease: 0.9 kg/liter (7.5 lb/gal) (avg)

Output product width: 72.4 cm - 152 cm (28.5 inch - 60 inch)

Number of Finishing Stands: Seven

Average concentration of hydrocarbon (as methane) emissions from Finishing Stands with application of rolling oils): 60 ppm*

80 inch Hot Strip Rolling temperature (slab from furnace): 1290 - 1430°C (2350 - 2600°F)

Hot reduction is accompanied with scale formation.

Working days = 84 percent of 365 days

Overall lubricants requirement: 0.26 kg/MT (0.53 lb/ton) steel product

Input = 1480 MT (1634 tons)

Output = 1480 MT (1634 tons)

---

*Inland Steel test results.

A consumption factor of 7.8 MT/yr (8.6 ton/yr) was estimated from these values. The leaks and spills on ground floor was estimated to be 0.0041 kg/MT of steel produced (0.007 lb/ton of steel). The last factor, solid trash and debris was determined to be 0.004 kg/MT of steel produced (0.007 lb/ton of steel). These estimates were used to develop a consumption factor of 11.9 MT/yr (13.1 tons/yr) for leaks and spills, and 11.9 MT/yr (13.1 tons/yr) for solid trash and debris.

5.5.2.3 Material Balance

Volatilized Hydrocarbons:

The hot reduction process in this hot strip mill uses rolling oil. The average total hydrocarbon (as methane) concentration was estimated to be 60 ppm in the surrounding air. This is equivalent to the emission level (60-75 ppm) in U.S. Steel, Gary Works' 84 inch hot strip mill (using rolling oil). Using 60 ppm, the volatilized hydrocarbon loss term becomes 140 MT/year (154 tons/yr).

Carbonized:

It was estimated that 30 percent of rolling oil was carbonized to graphitic form, resulting in a solid lubricant film on the work-rolls. This estimation was taken from data supplied by the participating steel firms. From these values, 178.9 MT/yr (197.2 tons/yr) of oil (6.6 percent of the total lubricant input) was estimated to be carbonized.

Scrap Loss:

A small amount, estimated to be 2.2 percent of the rolling oil used for hot reduction rolling is included on the scrap steel. This estimate accounts for 13.2 MT/yr (14.5 tons/yr) loss.

Combusted:

The temperatures encountered in hot reduction rolling are much higher than the fire points of lubricants used. Therefore, it is estimated that a significant fraction of total rolling oil is a combustion loss. The rolling oil loss terms are: volatilization, carbonization, scrap loss, and combustion. By balancing these terms, it is estimated that 264 MT/yr (291 ton/yr) of rolling oil is lost through combustion (44.3 percent of rolling oil).

Oil on Output Products:

As the temperatures encountered during hot reduction operation are much higher than the fire points of the lubricant, the oil on output products term is negligible.

Oil on Scales:

During the hot reduction process, scale formation was estimated to be 3.1 percent of steel strip produced. This scale contained 0.13 percent of oil. From these factors, the oil loss term was estimated to be 137 MT/yr (151 tons per year).

Sludge Disposal:

Sludge formation was estimated to be 1.88 percent of steel output products. It contains 0.625 percent oil. From these two factors, the oil loss on sludges was estimated to be 395 MT/yr (435 ton/yr).

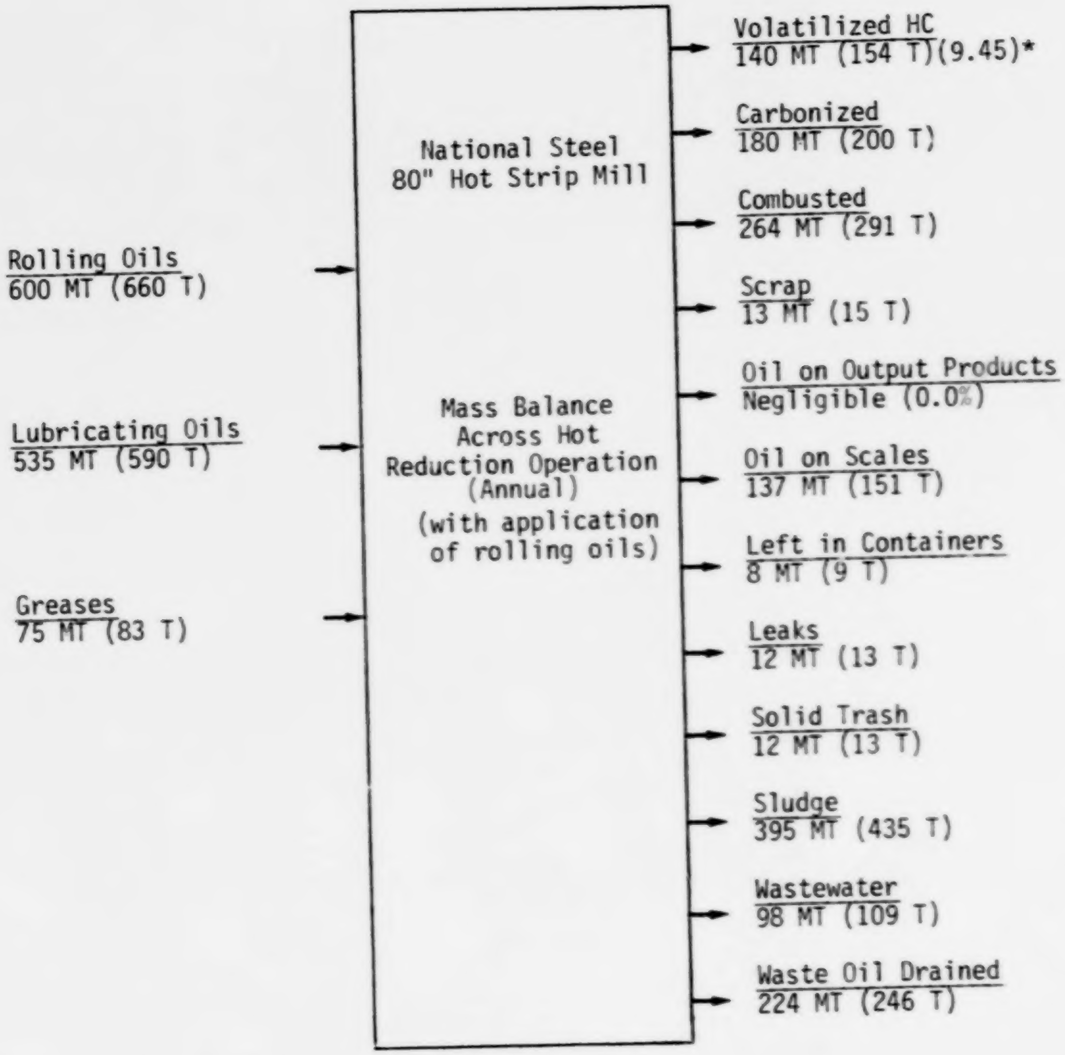
Waste oil drained and collected was estimated as the balance of the total loss, or 224 MT/yr (246 ton/yr).

The oil mass balance for the 80 inch hot strip mill is depicted in Figure 5-10. Table 5-11 presents the pertinent operating parameters used to develop the mass balance.

5.6 WHEELING-PITTSBURGH STEEL CORPORATION, STEUBENVILLE PLANT

A summary of the major rolling mills and products associated with the Wheeling-Pittsburgh, Steubenville Plant is presented in Table 5-12. The information presented is a summary of data provided in the AISI Directory of Iron and Steel Works.

Figure 5-10. 80" HOT STRIP MILL UTILIZING ROLLING OILS


National Steel
80" Hot Strip Mill
Mass Balance
Across Hot
Reduction Operation
(Annual)
(with application
of rolling oils)
Rolling Oils
600 MT (660 T)
Lubricating Oils
535 MT (590 T)
Greases
75 MT (83 T)
Volatilized HC
140 MT (154 T)(9.45)*
Carbonized
180 MT (200 T)
Combusted
264 MT (291 T)
Scrap
13 MT (15 T)
Oil on Output Products
Negligible (0.0%)
Oil on Scales
137 MT (151 T)
Left in Containers
8 MT (9 T)
Leaks
12 MT (13 T)
Solid Trash
12 MT (13 T)
Sludge
395 MT (435 T)
Wastewater
98 MT (109 T)
Waste Oil Drained
224 MT (246 T)

* Percent of total output.

Table 5-12. WHEELING - PITTSBURGH STEEL CORPORATION*

No.	Type of Mill	Annual Rolling Capacity	
1	Slabbing	1,527,000	3,137,000 Net Tons
1	Slabbing	1,610,000	
1	Hot Strip	2,636,000	4,427,000 Net Tons
1	Strip - Cont. (cold reducing)	576,000	
1	Sheet - (Cold finish)	150,000	
1	Sheet - Cont. (cold finish)	330,000	
1	Sheet - Cont. (cold finish)	322,000	
1	Sheet - Cont. (cold finish)	413,000	
8		7,564,000 NET TONS	

---

* Equipment and annual rolling capacity data from AISI Directory of Iron and Steel Works (1.0 ton = 907.2 kg).

A mass balance was performed for the 80 inch (six finishing stands) hot strip mill (with no rolling oil) at this facility. Stack or ambient hydrocarbon monitoring was not conducted at this mill.

5.6.1 80 INCH SIX FINISHING STAND HOT STRIP MILL

Table 5-13 outlines the basic process parameters for this hot reduction mill. It is the only mill not visited for which a mass balance was performed.

5.6.1.1 Lubricant Use

Yearly lubricant use at the 80 inch six finishing stand hot strip mill are as follows:

Lubricating oils	552 MT	(609 tons)
Greases	239 MT	(263 tons)
Hydraulic fluids	562 MT	(620 tons)
Total	1350 MT	(1490 tons)

Assuming 0.9 kg/l (7.5 lb/gal) for oils, the total oil, grease and hydraulic fluid input to the plant is 1,503,000 l/yr (397,000 gal/yr). An oil and grease consumption factor of 0.88 kg/MT of steel product (1.77 lb/ton) was calculated from these values.

5.6.1.2 Discharge to Wastewater Treatment Facilities and Other Losses

Data indicates that 214.3 MT/yr (236 tons/yr) of oil is lost through wastewater discharge to the treatment facility (0.14 kg oil/MT of steel product (0.28 lb oil/ton)).

Table 5-13. 80 INCH (SIX FINISHING STANDS) HOT STRIP MILL OPERATING AND LUBRICANT PARAMETERS (WHEELING - PITTSBURGH STEEL - STEUBENVILLE PLANT)

Production:

Design Capacity: 2.39×10^6 MT/yr
(2.64×10^6 tons/yr) (AISI data)

Actual production: 64% design capacity
= 1,530,000 Mt/yr (1,600,000 tons/yr)

Design capacity (Nationwide avg): 2.34×10^6 MT/yr
(2.58×10^6 tons/yr)

Density of steel products: (40.8 lb/sq.ft/1 inch (avg))

Density of oil, hydraulic fluid or grease: 0.9 kg/liter (7.5 lb/gal) (avg)

Output product width: 72.4 cm - 152 cm (28.5 inch - 60 inch)

Number of Finishing Stands: Six

Average concentration of hydrocarbon (as methane) emissions from Finishing Stands with application of rolling oils): 15 ppm (avg)*

80 inch Hot Strip Rolling temperature (slab from furnace):
1290 - 1430°C (2350 - 2600°F)

Hot reduction is accompanied with scale formation.

Working days = 84 percent of 365 days

Overall lubricants requirement: 0.88 kg/MT (1.77 lb/ton)
steel product

Input = 1350 MT (1490 tons)

Output = 1350 MT (1420 tons)

*U.S. Steel test results.

The quantities left in containers; leaks and spills on ground/floor; and solid trash were estimated to be 1.3 percent, 0.4 percent, and 0.4 percent of the total lubricant purchased, respectively. The left in containers term was derived from the following two values:

0.5 percent of oil and hydraulic fluid input (purchase)
5 percent of grease input (purchase)

A consumption factor of 17.5 MT/yr (19.3 ton/yr) was derived from this estimate. The leaks and spills on ground floor was estimated to be 0.004 kg/MT of steel produced (0.007 lb/ton of steel). The last factor, solid trash and debris was also estimated to be 0.004 kg/MT of steel produced (0.007 lb/ton of steel). A consumption factor of 5.4 MT/yr (6.0 ton/yr) for leaks and spills, and 5.4 MT/yr (6.0 ton/yr) for solid trash and debris were calculated from the estimated values.

5.6.1.3 Material Balance

Volatilized Hydrocarbons:

The hot reduction process does not employ rolling oils. The average total hydrocarbon (as methane) concentration was estimated to be 15 ppm, based on sampling performed at the USS Gary Works. Using this factor, the volatilized hydrocarbon loss term was estimated to be 22.3 MT/yr (24.6 ton/yr) of hydrocarbon emissions.

Oil on Output Products:

Temperatures encountered during the hot reduction process are much higher than the fire points of lubricants used, and oil remaining on the steel strip is estimated to be negligible.

Oil on Scales:

Scale formation was estimated to be 3.48 percent of steel strip produced. It is estimated to contain 0.53 percent of oil. From these two factors, the oil loss on scales was calculated to be 282 MT/yr (311 ton/yr).

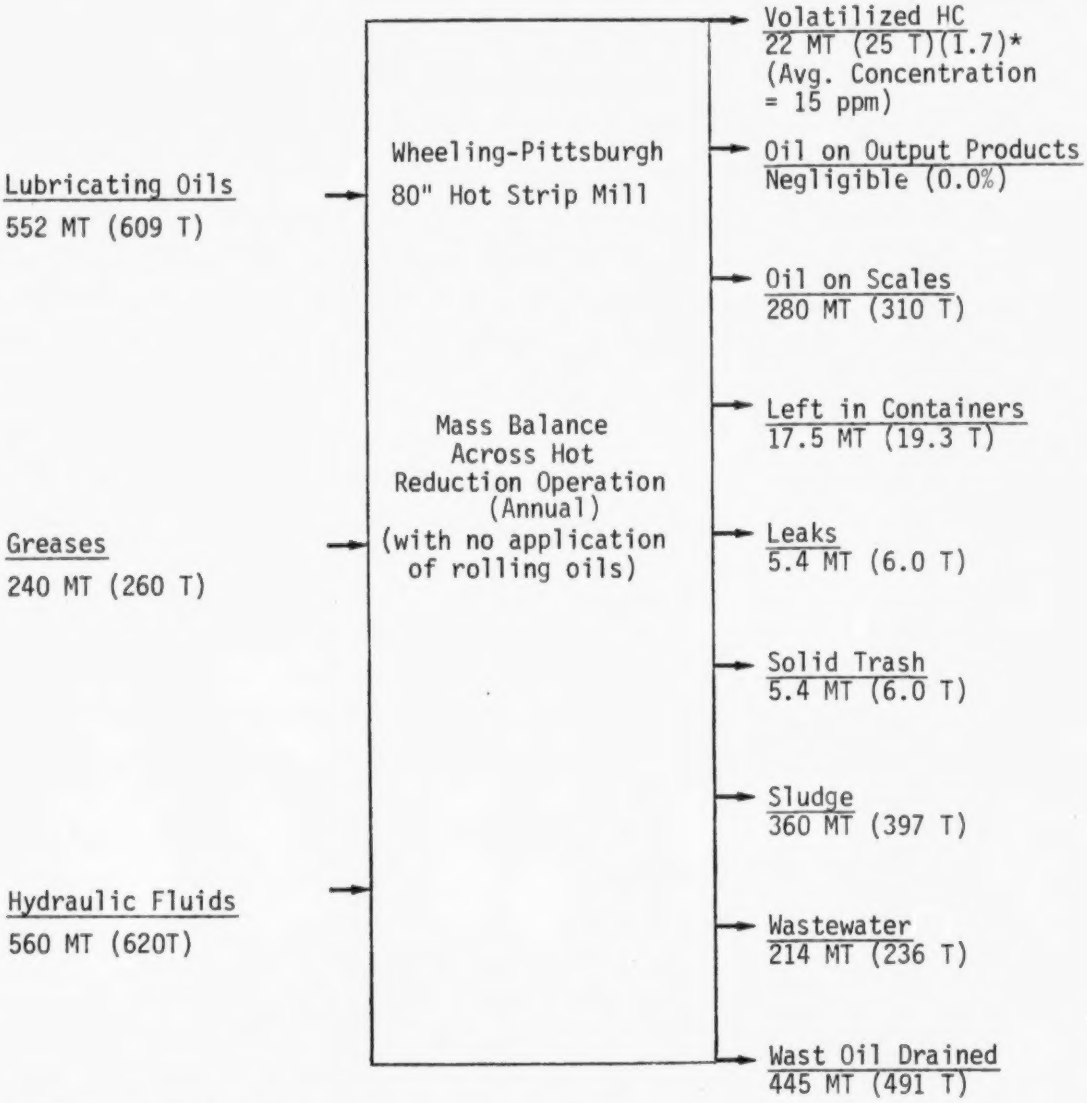
Sludge Disposal:

Sludge formation was estimated to be 1.88 percent of the steel processed and contained 1.25 percent of oil. Incorporating these two factors, the oil loss in sludges was estimated to be 360 MT/yr (397 ton/yr).

Waste oil drained and collected was estimated as the balance of the total loss or 445 MT/yr (490 ton/yr).

The oil mass balance for the 80 inch hot strip mill is depicted in Figure 5-11.

Figure 5-11. HOT STRIP MILL NOT UTILIZING ROLLING OILS


Lubricating Oils
552 MT (609 T)
Greases
240 MT (260 T)
Hydraulic Fluids
560 MT (620T)
Wheeling-Pittsburgh
80" Hot Strip Mill
Mass Balance
Across Hot
Reduction Operation
(Annual)
(with no application
of rolling oils)
Volatilized HC
22 MT (25 T)(1.7)*
(Avg. Concentration
= 15 ppm)
Oil on Output Products
Negligible (0.0%)
Oil on Scales
280 MT (310 T)
Left in Containers
17.5 MT (19.3 T)
Leaks
5.4 MT (6.0 T)
Solid Trash
5.4 MT (6.0 T)
Sludge
360 MT (397 T)
Wastewater
214 MT (236 T)
Wast Oil Drained
445 MT (491 T)

* Percent total output.

6.0 TYPICAL MILL

A summary of the data obtained from the steel rolling mills (cold strip mills and hot strip mills) is presented in this chapter, along with generalizations concerning lubricant use, and estimates of material balance loss terms. An effort has been made to present estimates for a typical hot strip rolling mill and cold strip rolling mill. Also, estimates are provided for total lubricant, oil, grease, and hydraulic fluid use by a typical hot strip and cold strip rolling mill in the United States.

Lubricant use depends upon the types and sizes of equipment, as well as the types and quantities of products associated with the steel rolling operation. The differences in the types and sizes of equipment, as well as the types and quantities of products associated with non-typical and specialty steel rolling mills may differ from those in a typical mill. This may significantly influence the quantity and types of lubricants and hydraulic fluids used. Differences in wastewater treatment facilities and waste oil recovery efforts, along with factors influencing use, could limit the similarities between specialty steel rolling mill and the typical rolling mill.

Typical hot strip mill production averaged on a nationwide basis is 2.34×10^9 kg/yr (2.58×10^6 tons/yr) whereas, typical cold strip mill production averaged on a nationwide basis is 1.18×10^9 kg/yr (1.3×10^6 tons/yr). The total steel production capacity of all continuous hot roll strip mills with a capacity over 907 kg/yr (1×10^6 tons/yr), and total steel production capacity of all continuous cold strip mills with a capacity over 820 kg/yr (0.9×10^6 ton/yr) in U.S.A. is 24×10^6 kg/yr (25×10^6 tons/yr) (see Tables 6-1 and 6-2). Estimates and generalizations have been made by PES for a "typical" steel mill. It should be pointed out that no two rolling mills are alike and describing in detail the equipment, lubricating practices and air or water pollution discharges at a typical steel

Table 6-1. CONTINUOUS HOT ROLL MILLS OVER 1×10^6 NET TON/YR

	COMPANY	NET TONS	SIZE
1)	ARMCO	2.800×10^6	86"
	(MIDDLETOWN WORKS)		
2)	BETHLEHEM	2.730×10^6	69"
	(SPARROWS PT.)	2.480×10^6	58"
3)	BETHLEHEM	2.520×10^6	96"
	(LACKAWANNA)		
4)	BETHLEHEM	3.500×10^6	50"
	(BURNS HARBOR)		
5)	FORD MOTOR CO.	2.900×10^6	68"
	(ROUGE)		
6)	INLAND STEEL	1.300×10^6	76"
	(INDIANA HARBOR)	1.700×10^6	44"
		3.700×10^6	80"
7)	JONES & LAUGHLIN	1.646×10^6	45"
	(Semi-Cont.)		
	(ALIQUIPPA)		
8)	JONES & LAUGHLIN	1.297×10^6	96"
	(PITTSBURGH)		
9)	JONES & LAUGHLIN	3.360×10^6	80"
	(CLEVELAND)		
10)	KAISER	1.500×10^6	89"
	(FONTANA)		
11)	NATIONAL STEEL	4.400×10^6	80"
	(GREAT LAKES)		
12)	NATIONAL STEEL	3.100×10^6	54"
	(WEIRTON)		
13)	REPUBLIC	2.210×10^6	58"
	(MAHONING)		

Table 6-1. (Cont.) CONTINUOUS HOT ROLL MILLS OVER 1 x 10^6 NET TON/YR

	COMPANY	NET TONS	SIZE
14)	REPUBLIC (CLEVELAND)	2.210 x 10^6	84"
15)	REPUBLIC (SOUTHERN DIST)	1.210 x 10^6	84"
16)	SHARON STEEL CORP. (STEEL DIV)	1.680 x 10^6	80"
17)	U.S. STEEL (DRAVOSBURG)	2.568 x 10^6	76"
18)	U.S. STEEL (FIARLESS)	2.800 x 10^6	76"
19)	U.S. STEEL (GARY)	3.083 x 10^6	80"
20)	U.S. STEEL (FAIRFIELD)	1.600 x 10^6	60"
21	YOUNGSTOWN SHEET (CAMPBELL)	2.476 x 10^6	79"
22)	YOUNGSTOWN SHEET (INDIANA HARBOR)	3.000 x 10^6	84"

Typical Mill Average: 2.58 x 10^6 tons/yr (Nationwide)

Reference: AISI Directory of Iron & Steel Works of United States and Canada. 34th Edition.

Table 6-2. COLD REDUCTION MILLS OVER 0.9 x 10^6 NET TONS/YR

	COMPANY	NET TONS	SIZE
1)	ARMCO (MIDDLETOWN WORKS)	1.000 x 10^6	80"
2)	BETHLEHEM (SPARROW PT.)	1.270 x 10^6	66"
3)	BETHLEHEM (LACKAWANNA)	1.080 x 10^6	75"
4)	BETHLEHEM (BURNS HARBOR)	1.070 x 10^6	80"
5)	FORD MOTOR CO. (ROUGE)	.968 x 10^6	66"
6)	INLAND STEEL (INDIANA HARBOR)	1.000 x 10^6	56"
7)	JONES & LAUGHLIN (CLEVELAND)	1.156 x 10^6	77"
8)	JONES & LAUGHLIN (HENNEPIN)	1.260 x 10^6	84"
9)	NATIONAL STEEL (GREAT LAKES)	1.500 x 10^6	80"
10)	NATIONAL STEEL (WEIRTON)	1.200 x 10^6	93"
11)	MIDWEST STEEL (NAT'L STEEL) (PORTAGE)	1.400 x 10^6	80"
12)	REPUBLIC (CLEVELAND)	2.375 x 10^6	84"
13)	U.S. STEEL (DRAVOSBURG)	1.656 x 10^6	84"

Table 6-2. (Cont.) COLD REDUCTION MILLS OVER 0.9 x 10^6 NET TONS/YR

	COMPANY	NET TONS	SIZE
14)	U.S. STEEL (FAIRLESS)	1.250 x 10^6	80"
15)	U.S. STEEL	1.200 x 10^6	56"
	(GARY)	1.050 x 10^6	84"
		1.590 x 10^6	80"
16)	YOUNGSTOWN SHEET (INDIANA HARBOR)	.900 x 10^6	56"

Typical Mill Average: 1.3 x 10^6 tons/yr (Nationwide)

Reference: AISI Directory of Iron & Steel Works of United States and Canada. 34th Edition.

rolling mill would be difficult. Whenever data and circumstances permit, the lubricant use and resulting air and water pollution discharges should be studied on a case by case basis. The generalizations and estimates are intended to be used as a basis from which further detailed investigations can be initiated. The generalizations and estimates for the "typical" mill can only illustrate the relative magnitude and significance of various loss terms investigated.

6.1 TYPICAL COLD STRIP MILL (COLD REDUCTION OPERATION)

Estimates and generalizations have been made separately for a typical cold strip mill and for a typical hot strip mill.

6.1.1. CONSUMPTION OF LUBRICANTS, OILS, GREASES, AND HYDRAULIC FLUIDS

The consumption data obtained from four cold strip mills are summarized in Table 6-3. As mentioned elsewhere, the types and consumption rates of lubricants, oils, greases, and hydraulic fluids in a steel rolling mill are influenced by several factors. Two key parameters, steel production rate and the type of products made, have been considered. In Table 6-3 the consumption data, broken down by rolling oil, lubricating oil, hydraulic fluid, and grease are tabulated along with the actual steel production of the steel rolling mill. The last column in Table 6-3 indicates the consumption factor for rolling oil, lubricating oil, hydraulic fluid, and grease in a "typical" cold strip mill. The consumption factor of lubricating oil used in "typical" rolling mill has been estimated as arithmetic average of the factors of lubricating oil used in all four rolling mills. The consumption factor of the hydraulic fluid used in "typical" rolling mill has also been estimated as arithmetic average of the factors of hydraulic fluids used in all the four rolling mills. The consumption factor of the grease used in "typical" rolling mills has been estimated as arithmetic average of the factors of grease used in all the four rolling mills. These consumption data were converted to mass units,

Table 6-3. CONSUMPTION OF ROLLING OIL, LUBRICATING OIL, HYDRAULIC FLUID OR GREASE IN Kg/MT (lb/ton) STEEL PRODUCT FOR COLD STRIP MILL IN DIFFERENT STEEL PRODUCING FACILITIES

	Inland Steel		National Steel	U.S. Steel	Typical Cold Strip Mill
	56" 4-Stand	80" 5-Tandem	80"-93" Cold Reduction Area	80" 5-Stand	(Cold Reduction)
Rolling Oil	0.047 Kg/MT (0.096 lb/ton)	0.011 Kg/MT (0.023 lb/ton)	0.17 Kg/MT (0.36 lb/ton)	0.62 Kg/MT (1.27 lb/ton)	0.49 Kg/MT (0.81 lb/ton)
Lubricating Oil	0.23 Kg/MT (0.48 lb/ton)	0.14 Kg/MT (0.29 lb/ton)	0.19 Kg/MT (0.38 lb/ton)	0.63 Kg/MT (1.30 lb/ton)	0.32 Kg/MT (0.65 lb/ton)
Hydraulic Fluid	—	—	0.32 Kg/MT (0.66 lb/ton)	0.53 Kg/MT (1.083 lb/ton)	0.43 Kg/MT (0.87 lb/ton)
Grease	0.023 Kg/MT (0.047 lb/ton)	—	0.0034 Kg/MT (0.0069 lb/ton	0.0052 Kg/MT (0.011 lb/ton)	0.013 Kg/MT (0.023 lb/ton)
Total	0.30 Kg/MT (0.62 lb/ton)	0.16 Kg/MT (0.32 lb/ton)	0.69 Kg/MT (1.40 lb/ton)	1.79 Kg/MT (3.66 lb/ton)	1.15 Kg/MT (2.35 lb/ton)

using an oil density factor of 0.9 kg/liter (7.5 lb/gal.) factor for all types of lubricant, oil, grease or hydraulic fluid. It must be pointed out that the consump- tion data provided by the steel mills did not include all required information. The effect of this lack of information is to add uncertainty in this material balance loss terms.

According to these calculations, it is estimated that about 1.4×10^6 kg/yr (1500 tons/yr) of oils, greases, lubricants and hydraulic fluids are used by a typical cold strip mill.

6.1.2 MATERIAL BALANCE LOSS TERM ESTIMATES

More than 84 percent of all lubricants, oils, greases, and hydraulic fluids used in a steel-making facility are associated with cold strip rolling and hot strip rolling operations. The iron-making, steel-producing, and auxiliary processes account for the remaining 16 percent.

The lubricant, oil, grease and hydraulic fluid consumption data obtained from steel mills and other relevant sources have been summarized and correlated with various parameters resulting in material loss terms estimates for "typical" cold strip mills. A "typical" cold strip rolling mill with annual production capacity of 1.3×10^6 tons/year was selected.

The material balance loss terms estimated for Inland Steel (56 inch four-stand and 80 inch five-stand) provided the basis for calculating average loss terms. Table 6-4 summarizes the loss term data expressed as percentages of the total lubricants, oils, greases, and hydrualic fluids input into each cold strip rolling mill. The loss term "drained and collected" has been estimated as the balance of the total loss.

Stack test data were obtained for the 56 inch four-stand and 80 inch five-stand Inland Steel cold rolling operations. From these data, the average value of each loss term was computed for a "typical"

Table 6-4. PERCENTAGE DISTRIBUTION OF TOTAL LUBRICANT (OIL, HYDRAULIC FLUID, GREASE, AND ROLLING OIL TOGETHER) CONSUMPTION THROUGH VARIOUS LOSS TERMS IN DIFFERENT COLD STRIP REDUCTION MILLS

	Inland Steel		National Steel	U.S. Steel	Typical Cold Strip Mill
	56" 4-Stand	80" 5-Stand	80"-93" Cold Reduction Area	80" 5-Stand	(Cold Reduction)
Volatized	20.8%	26.9%	23.9%	23.9%	23.9%
Oil on Products	10	15.1	12.6	12.6	12.6
Left in Containers	0.8	0.5	0.7	0.7	0.7
Leak, Spill	1.1	2.3	1.7	1.7	1.7
Trash, Debris	1.1	2.3	1.7	1.7	1.7
Wastewater	18.4	8.8	13.6	13.6	13.6
Drained, Collected*	47.6	44	45.8	45.8	45.8
Total	100%	100%	100%	100%	100&

* Balance

cold strip mill, as well as for National Steel and U.S. Steel. Stack sampling for hydrocarbon emissions was not conducted in National Steel and U.S. Steel, and the percentage of total lubricants input volatilized for these two mills is assumed equal to that in "typical" mill. The last column of Table 6-4 indicates the value selected as representative of a "typical" steel mill.

The material balance loss terms for a typical mill are tabulated in Table 6-5 and Figure 6-1, and are defined in Chapter 5.

6.2 TYPICAL HOT STRIP MILL (HOT REDUCTION OPERATION)

Estimates and generalizations have been made separately for a typical hot strip mill and for a typical cold strip mill.

6.2.1 CONSUMPTION OF LUBRICANTS, OILS, GREASES AND HYDRAULIC FLUIDS

The consumption data obtained from five hot strip mills are summarized in Table 6-6. As previously mentioned, the types and consumption rates of lubricants, oils, greases, and hydraulic fluids in a hot rolling mill are influenced by several factors. Two key parameters, steel production rate and the type of products made, have been considered. In Table 6-6, the consumption data broken down by rolling oil, lubricating oil, hydraulic fluid and grease are tabulated along with the actual steel production of the steel rolling mill. The last column in Table 6-6 indicates consumption factor of rolling oil, lubricating oil, hydraulic fluid, and a grease in a "typical" hot strip mill - with rolling oil, and without rolling oil.

The consumption factor of rolling oil used in a "typical" rolling mill (with rolling oil usage) has been estimated as the arithmetic average of rolling oil consumption factors used in National Steel and U.S. Steel. The lubricating oil consumption factor is a "typical" mill (with and without rolling oil) was estimated as an average of those in all the mills - Inland Steel, National Steel, U.S. Steel and Wheeling-Pittsburgh (with and without rolling oil).

Table 6-5. TYPICAL COLD STRIP TANDEM MILL OPERATING AND LUBRICANT PARAMETERS (COLD REDUCTION OPERATING)

Production: Annual Rolling Capacity (Nationwide average):

1.3×10^6 MT/yr. ($1.3 \times 10^6 \frac{\text{tons}}{\text{yr}}$)

Actual production = 60% x annual rolling capacity
= 7.08×10^5 MT/yr
(0.78×10^6 tons/yr)

Density of steel: 40.8 lb/sq ft/1 inch (avg.)

Density of oil, grease or hydraulic fluid: 0.9 kg/liter (7.5 lb/gal)

Total number of working days : 60% of 365 days

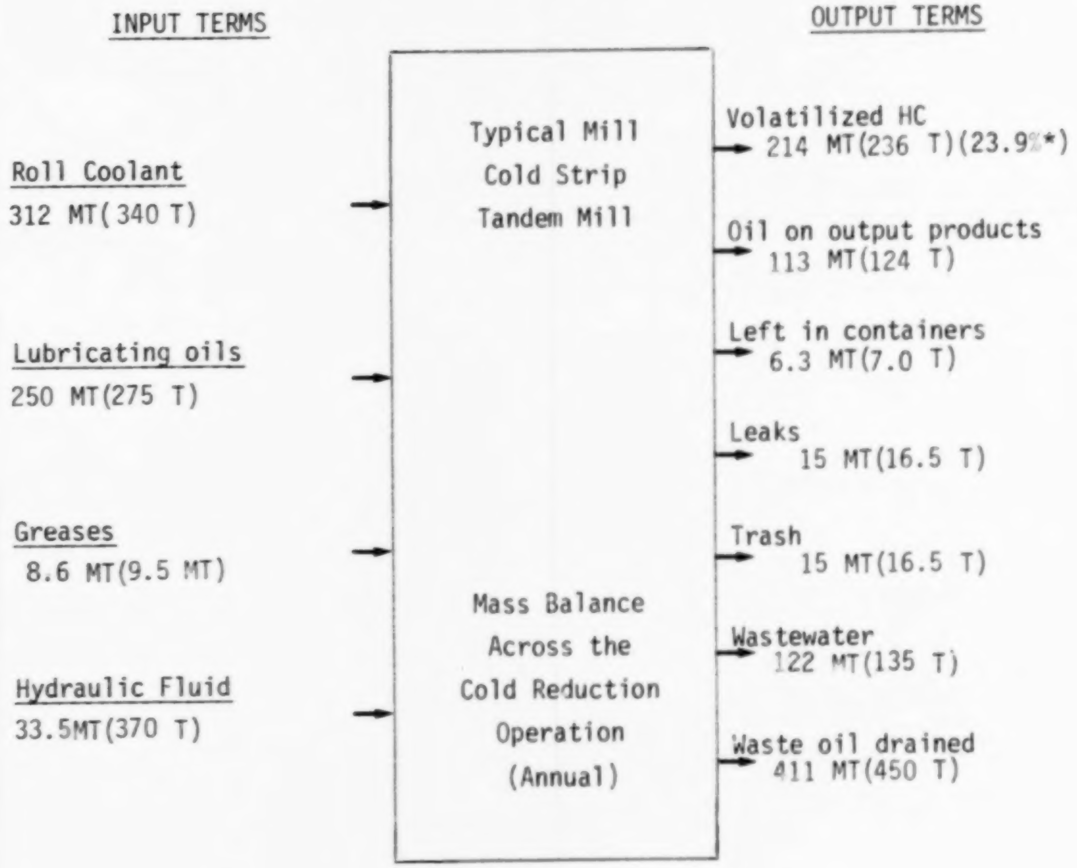
Resultant steel temperature: 65-121°C

Cold reduction - No scale formation

Total lubricants (rolling oil, lubricant, grease and hydraulic fluid) required: 1.152 kg/MT (2.352 lb/ton)(average)

Input: 897 MT (990 ton) Output: 897 MT (990 ton)

Figure 6-1. TYPICAL COLD STRIP MILL LUBRICATION MASS BALANCE


INPUT TERMS
OUTPUT TERMS
Typical Mill
Cold Strip
Tandem Mill
Roll Coolant
312 MT(340 T)
Lubricating oils
250 MT(275 T)
Greases
8.6 MT(9.5 MT)
Hydraulic Fluid
33.5MT(370 T)
Mass Balance
Across the
Cold Reduction
Operation
(Annual)
Volatilized HC
214 MT(236 T)(23.9%*)
Oil on output products
113 MT(124 T)
Left in containers
6.3 MT(7.0 T)
Leaks
15 MT(16.5 T)
Trash
15 MT(16.5 T)
Wastewater
122 MT(135 T)
Waste oil drained
411 MT(450 T)

* Percent of total output.

Table 6-6. CONSUMPTION OF ROLLING OIL, LUBRICATING OIL, HYDRAULIC FLUID, OR GREASE IN Kg/MT (lb/ton) STEEL PRODUCT FOR HOT STRIP MILL IN DIFFERENT STEEL PRODUCING FACILITIES.

	Inland Steel	National Steel	U.S. Steel		Wheeling-Pittsburgh	Typical Hot Strip Mill	
	(without rolling oil)	(with rolling oil)	(without rolling oil)	(with rolling oil)	(without rolling oil)	(with rolling oil)	(without rolling oil)
Rolling Oil	0.00096*Kg/MT (0.0020 lb/ton	0.17 Kg/MT (0.36 lb/ton)	—	0.28 Kg/MT (0.57 lb/ton)	—	0.23 Kg/MT (0.46 lb/ton)	—
Lubricating Oil	0.31 Kg/MT (0.63)	0.16 Kg/MT (0.32)	0.87 Kg/MT (1.78)	0.87 Kg/MT (1.78)	0.35 Kg/MT (0.72)	0.51 Kg/MT (1.044)	0.51 Kg/MT (1.044)
Hydraulic Fluid	0.0024 Kg/MT (0.0049)*	0.081 Kg/MT (0.16)	0.013Kg/MT (0.026)	0.013Kg/MT (0.026)	0.36 Kg/MT (0.73)	0.047 Kg/MT (0.095)	0.093 Kg/MT (0.19)
Grease	0.083 Kg/MT (0.17)	0.023 Kg/MT (0.045)	0.10 Kg/MT (0.21)	0.10 Kg/MT (0.21)	0.15 Kg/MT (0.31)	0.063 Kg/MT (0.13)	0.11 Kg/MT (0.23)
Total	0.40 Kg/MT (0.81)	0.43 Kg/MT (0.88)	0.99 Kg/MT (2.017)	1.27 Kg/MT (2.59)	0.87Kg/MT (1.77)	0.85 Kg/MT (1.73)	0.72 Kg/MT (1.47)

* Insignificant

The hydraulic oil consumption factor for a typical mill (with rolling oil) is also the average of the consumptions in National Steel and U.S. Steel, whereas this factor for typical mill (without rolling oil) is one-half of the average of those consumed in the U.S. Steel and Wheeling-Pittsburgh facilities. The values have been estimated to be 50 percent of their average since the magnitude of the two available inputs differed by a factor greater than 100.

The grease consumption factor for a typical mill (with rolling oil) is the average of those in National Steel and U.S. Steel, whereas this factor for the typical mill rolling oil is the average of those in U.S. Steel, Inland Steel, and Wheeling-Pittsburgh. The consumption data were converted to mass units, using 0.9 kg/liter (7.5 lb/gal) factor for all types of lubricant, oil, grease, and hydraulic fluid. It must be pointed out that the consumption data provided by the steel mills did not include all required information. The effect of this lack of appropriate and adequate information is to add uncertainty in the material balance loss terms.

According to these calculations, it is estimated that about 2.03×10^6 kg/yr (2200 tons/yr) of lubricants, oils, greases and hydraulic fluids are used by a typical hot strip mill in the United States.

6.2.2 MATERIAL BALANCE LOSS TERMS ESTIMATES

The lubricant, oil, grease, and hydraulic fluid consumption data obtained from steel mills and the other relevant sources have been summarized and correlated with various parameters resulting in material loss terms estimate for a "typical" hot strip mill (with and without rolling oil). A typical hot strip rolling mill with an annual production capacity of 2.58×10^6 tons was selected.

The material balance loss terms estimated for Inland Steel, U.S. Steel, and Wheeling-Pittsburgh provided the basis for calculating average loss terms for a typical hot strip mill (with and without rolling oil usage). Table 6-7 summarizes the loss term data expressed as percentages of the total lubricants, oils, greases and hydraulic

Table 6-7. PERCENTAGE DISTRIBUTION OF TOTAL LUBRICANT (OIL, HYDRAULIC FLUID, GREASE, AND ROLLING OIL TOGETHER) CONSUMPTION THROUGH VARIOUS LOSS AREAS IN DIFFERENT HOT STRIP REDUCTION MILLS

	Inland Steel	National Steel	U.S. Steel		Wheeling-Pittsburgh	Typical Hot Strip Mill	
	(without rolling oil)	(with rolling oil)	(with rolling oil)	(without rolling oil)	(without rolling oil)	(with rolling oil)	(without rolling oil)
Volatized	1.89%	9.45%	6.4%	1.6%	1.7%	7.9%	1.7%
Carbonized	—	12.1	6.6	—	—	9.4	—
Combusted	—	17.8	9.7	—	—	13.8	—
Scrap Products	—	0.9	0.5	—	—	0.7	—
Oil on Products	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oil on Scales	7.44	9.3	14.5	18.6	20.9	11.9	15.6
Left in Containers	1.45	0.5	0.9	1.1	1.3	0.7	1.3
Leak, Spill	0.88	0.8	0.3	0.4	0.4	0.5	0.6
Trash, Debris	0.88	0.8	0.3	0.4	0.4	0.5	0.6
Sludge Formation	29.2	26.6	36.4	46.7	26.6	31.5	34.2
Waste water	34.8	6.6	9.1	11.7	15.8	7.8	20.8
Drained,* collected	23.5	15.1	15.3	19.6	32.9	15.3	25.2
Total	100%	100%	100%	100%	100%	100%	100%

* Balance

fluids input into each cold strip rolling mill. The loss term "drained and collected" has been estimated as the balance of the total loss.

Data were supplied by Inland Steel, U.S. Steel, National Steel, and Wheeling-Pittsburgh steel mills. Sampling for total hydrocarbons (as methane) was conducted at the 84 inch hot strip mill's finishing stands area in U.S. Steel, Gary Works. From these data, the average value of each loss term was computed for a "typical" hot strip mill. The hydrocarbon emission level due to volatilization of rolling oil in other steel rolling mills (National Steel, Inland Steel, and Wheeling-Pittsburgh) was estimated to be at a similar order of magnitude to that measured in U.S. Steel, 84 inch hot strip mill's finishing stands area. The last column in Table 6-7 indicates the value selected as representative of a "typical" steel mill (with and without rolling oil).

The material balance loss terms are tabulated in Table 6-8 and 6-9, and Figures 6-2 and 6-3. The material loss terms that are discussed in the above tables are defined in Section 5.2.

Table 6-8. TYPICAL HOT STRIP MILL OPERATING AND LUBRICANT PARAMETERS (WITH NO APPLICATION OF ROLLING OILS)

Production:

Design capacity (Nationwide average):
2.34×10^6 MT/yr (2.58×10^6 tons/yr)

Actual production: 76% x design capacity

Density of steel products: 40.8 lb/sq ft/1 inch (avg)

Density of oils, hydraulic fluid or grease: 0.9 kg/liter (7.5 lb/gal)

Output product width range: 45.7 cm - 194.3 cm (18 inch - 76.5 inch)

Number of finishing stands range: 7-12

Hot strip rolling temperature (slab from furnace): 1288-1427°C (2350-2600°F)

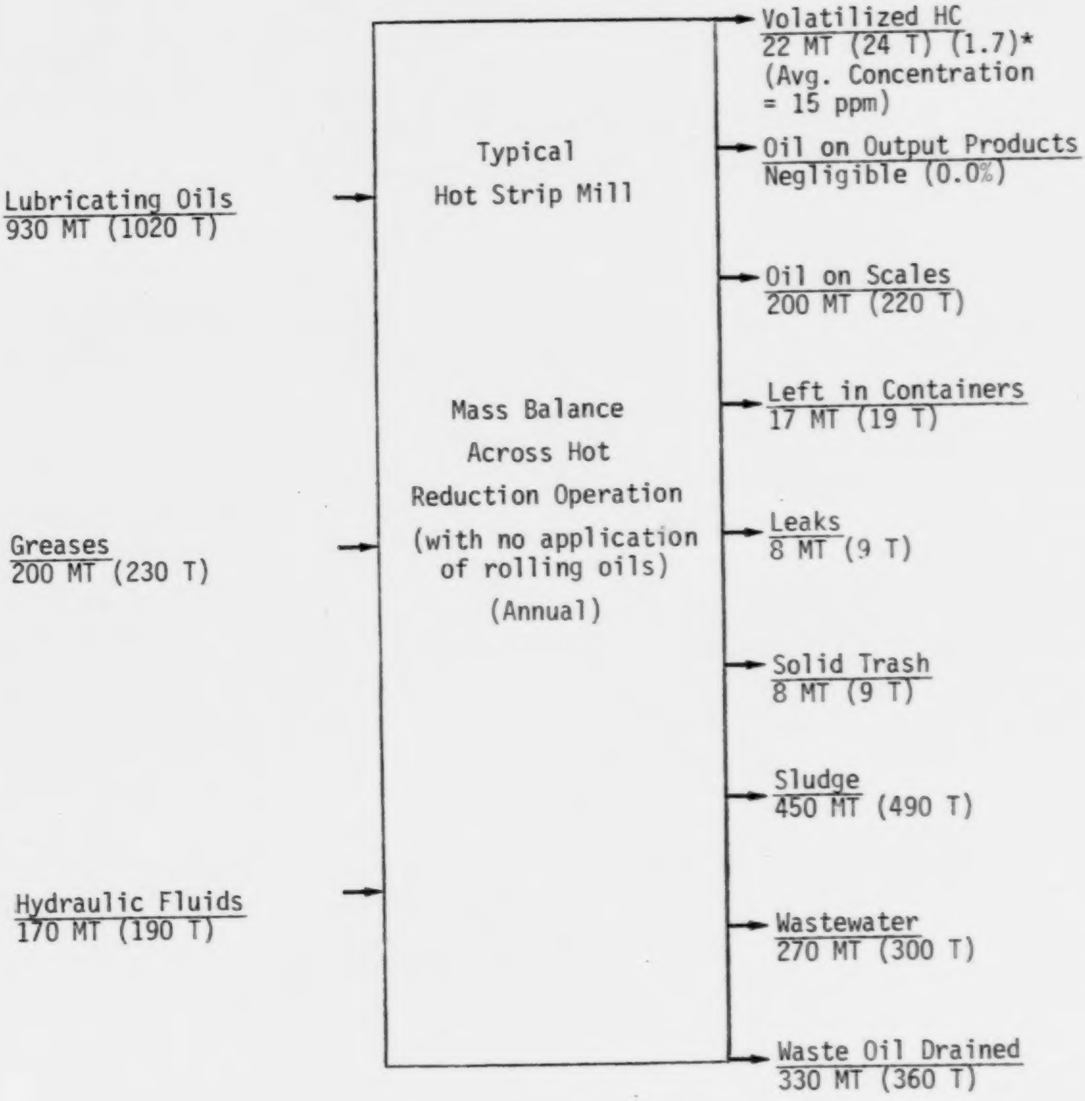
Total number of working days = 76% of 365 days

Average concentration of hydrocarbon emissions (with no application of rolling oils): 15 ppm (avg)

Overall lubricants requirement: 0.72 kg/MT (1.47 lb/ton)

Input: 1300 MT (1440 tons)   Output: 1300 MT (1440 tons)

Figure 6-2. HOT STRIP MILL NOT UTILIZING ROLLING OILS


Lubricating Oils
930 MT (1020 T)
Greases
200 MT (230 T)
Hydraulic Fluids
170 MT (190 T)
Typical
Hot Strip Mill
Mass Balance
Across Hot
Reduction Operation
(with no application
of rolling oils)
(Annual)
Volatilized HC
22 MT (24 T) (1.7)*
(Avg. Concentration
= 15 ppm)
Oil on Output Products
Negligible (0.0%)
Oil on Scales
200 MT (220 T)
Left in Containers
17 MT (19 T)
Leaks
8 MT (9 T)
Solid Trash
8 MT (9 T)
Sludge
450 MT (490 T)
Wastewater
270 MT (300 T)
Waste Oil Drained
330 MT (360 T)

* Percent total output.

Table 6-9. TYPICAL HOT STRIP MILL OPERATING AND LUBRICANT PARAMETERS (WITH APPLICATION OF ROLLING OILS)

Production:

Design capacity (Nationwide average):
2.34×10^6 MT/yr (2.58×10^6 tons/yr)

Actual production: 76% x Design capacity:
1.78×10^6 MT/yr (1.96×10^6 tons/yr)

Density of steel products: 40.8 lb/sq.ft/1 inch

Density of oils, hydraulic fluid or grease: 0.9 kg/liter (7.5 lb/gal) (avg.)

Output product width range: 45.7 cm - 194.3 cm (18 inch - 76.5 inch)
Number of Finishing Stands range: 7 - 12
Hot Strip Rolling temperature (slab from furnace): 1288-1427°C (2350 - 2600°F)

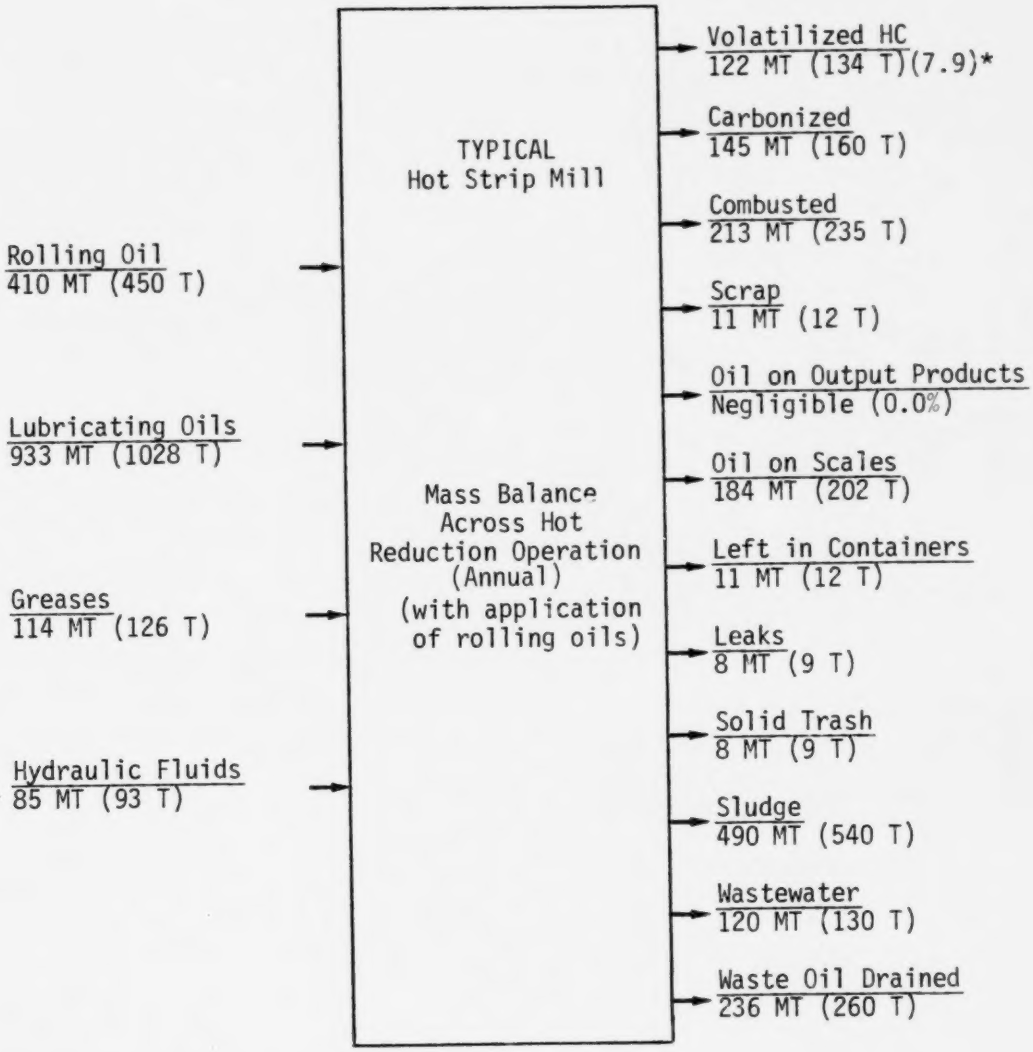
Total number of working days = 76% of 365 days

Average concentration of hydrocarbon emissions (with application of rolling oils): 60-75 ppm

Overall lubricants requirement: 0.89 kg/MT (1.73 lb/ton)

Input: 1540 MT (1700 tons)   Output: 1540 MT (1700 tons)

Figure 6-3. HOT STRIP MILL UTILIZING ROLLING OILS


TYPICAL
Hot Strip Mill
Mass Balance
Across Hot
Reduction Operation
(Annual)
(with application
of rolling oils)
Rolling Oil
410 MT (450 T)
Lubricating Oils
933 MT (1028 T)
Greases
114 MT (126 T)
Hydraulic Fluids
85 MT (93 T)
Volatilized HC
122 MT (134 T)(7.9)*
Carbonized
145 MT (160 T)
Combusted
213 MT (235 T)
Scrap
11 MT (12 T)
Oil on Output Products
Negligible (0.0%)
Oil on Scales
184 MT (202 T)
Left in Containers
11 MT (12 T)
Leaks
8 MT (9 T)
Solid Trash
8 MT (9 T)
Sludge
490 MT (540 T)
Wastewater
120 MT (130 T)
Waste Oil Drained
236 MT (260 T)

* Percent of total output.

7.0 DATA SUMMARY AND GENERALIZATIONS

A summary of the data obtained from the nine rolling mills is presented in this section along with generalizations concerning steel mill lubricant use and material balance estimates.

Only rolling operations which had capacities greater than 0.82 x 10^6 MT (0.9 x 10^6 ton) of steel per year were surveyed in the study. Specifically, only hot and cold strip mills were studied. The applicability to rolling operations other than hot and cold strip mills (i.e., structural, rail, billet, etc.) were not tested or investigated. The differences in the types and sizes, as well as the types and quantities of products associated with these other rolling operations may significantly influence the quantity and types of lubricants and hydraulic fluids used. Differences in wastewater treatment facilities and waste oil recovery efforts, along with the factors influencing lubricant usage, could also limit the similarities between strip mills and other rolling operations. Also, the lack of complete and accurate lubricant use data may further reduce the reliability of all estimates made.

Three basic approaches were used for identifying and quantifying the volatilized portion of lubricants used by large rolling operations: (1) mass balance; (2) actual source testing; and (3) laboratory simulation. Tables 7-1, 7-2, and 7-3 portray the emission profiles for a cold mill, hot mill, and typical mill respectively. These figures were gathered from information developed by utilizing all three data assembly approaches. An attempt to correlate the results of this study with those of the previous study, The Use and Fate of Lubricants, Oil, Greases, and Hydraulic Fluids in the Iron and Steel Industry, (EPA 600/2-78-101) was performed only for the typical mill.

If one considers that the final product of typical mill passes through one hot roll and one cold roll process prior to sale, 12.5 percent of the lubricants purchased will volatilize. The previous

Table 7-1. TYPICAL COLD MILL EMISSION RESULTS

1. Annual capacity (design) of "typical" cold strip mill (cold reduction process):*

   1.18×10^6 MT/yr (1.3×10^6 tons/yr)

2. Annual capacity (design) of all cold strip mills in U.S.A.:

   23.6×10^6 MT/yr (26×10^6 tons/yr)

3. Average lubricant consumption:

   1496 MT/yr (1650 ton/yr)

4. Total hydrocarbon (expressed as methane) emissions from "Typical" cold strip mill:

   358 MT/yr (395 ton/yr)

5. Total hydrocarbon (expressed as methane) emissions from cold strip mills in U.S.A.:

   7160 MT/yr (7900 ton/yr)

6. "Typical" cold strip mill - total hydrocarbon (as methane) emission factor:

   0.275 kg volatilized hydrocarbons per metric ton annual (design) capacity (0.55 lb/ton)

---

*Cold Strip Mills with annual capacity equal to or greater than 0.9×10^6 ton/yr were considered in the derivation of the national average ("typical" cold strip mill).

Table 7-2. TYPICAL HOT STRIP MILL EMISSION RESULTS

1. Annual Capacity (design) of "typical" hot strip mill (hot reduction process):*

   2.34×10^6 MT/yr (2.58×10^6 tons/yr)

2. Annual capacity (design) of hot strip mills in U.S.A.:

   60.8×10^6 MT/yr (67×10^6 tons/yr)

3. Average lubricant consumption:

   2140 kg/yr (2350 ton/yr)

4. Total hydrocarbon (expressed as methane) emissions from "typical" hot strip mill:

   94.7 MT/yr (104 ton/yr)

5. Total hydrocarbon (expressed as methane) emissions from hot strip mills in U.S.A.:

   2,460 MT/yr (2700 ton/yr)

6. "Typical" hot strip mill total hydrocarbon (as methane) emission factor:

   0.037 kg volatilized hydrocarbons per metric ton annual (design) capacity (0.074 lb/ton)

---

*Hot Strip Mills with annual capacity equal to or greater than 1.0×10^6 ton/yr were considered in the derivation of the national average ("typical" hot strip mill). An average of 50 percent of all hot strip mills were considered to utilize rolling oils in the above calculations.

Table 7-3. TYPICAL PLANT ROLLING MILL EMISSION RESULTS

1. Total hydrocarbon emissions from cold strip mills and hot strip mills in U.S.A.:

   9,620 MT/yr (10,600 ton/yr)

2. Typical steel rolling mill total hydrocarbon emission factor:

   $nEF_{hot} + mEF_{cold} = EF_{rolling}$

   EF_{hot} = 0.037 kg/MT (0.74 lb/ton)

   EF_{cold} = 0.27 kg/MT (550 lb/ton)

   n = number of hot rolling operations performed on a ton of steel (i.e., 1, 2, 3,...).

   m = number of cold rolling operations performed on a ton of steel (i.e., 1, 2, 3,...).

   EF= Emission Factor

If one assumes one cold and hot roll operation for each ton of steel, then:

(1)(0.037 kg/ton) + (1)(0.27 kg/ton) = 0.31 kg/ton (0.62 lb/ton)

3. Typical integrated steel mill produces approximately 3.6×10^6 MT/yr (4×10^6 ton/yr) of rolled product and utilizes 6.5×10^6 kg/yr (14.4×10^6 lb/yr) of lubricants per year.

4. 83.3 percent of the total lubricants purchased by a typical integrated steel mill are used in rolling mills.

   $.833 \times 6.5 \times 10^6$ kg/yr = 5.4×10^6 kg/yr (11.9×10^6 lb/yr) study concluded that of the total quantity of oil, grease, and hydraulic fluid used at a typical plant, approximately ten percent enters the environment as air pollution (see Reference 2). This study determined that the volatilization of lubricants used in rolling operations constituted 10.4 percent of all lubricants utilized within an integrated steel mill complex.

The above determination was based on the following calculations:

1. Typical integrated steel mill utilizes 6.5×10^6 kg/yr of lubricants;
2. 83.3 percent of steel plant lubricants are used in rolling operations; and
3. 12.5 percent of rolling lubricants are volatilized;

The percent of total plant lubricant volatilized due to roll operations equals:

$$\frac{(6.5 \times 10^6 \text{ kg/yr})\ (.833)\ (.125)}{(6.5 \times 10^6 \text{ kg/yr})} (100\%) = 10.4\%$$

or $(6.5 \times 10^6 \text{ kg/yr})\ (.104) = 6.75 \times 10^5 \text{ kg/yr}\ (1.5 \times 10^6 \text{ lb/yr})$

This figure does not incorporate the volatilization from the 16.7 percent of lubricants used in other areas of a steel mill complex. The total volatilization from these operations are estimated to add another one to two percent to the total volatilization figure (i.e., 11.4 percent to 12.4 percent lubricant volatilized within entire steel mill facility).

All emissions were described as hydrocarbon emissions. No determination of the degree of photochemical reactivity was made for the volatilized lubricants. The G.C. analysis revealed that the original composition of the rolling solutions used as lubricants on both cold and hot mills was changed after the rolling operation. The rolling solution would react in either one or more of the following ways: combustion, carbonization or decomposition. For example, the palm oil used in the laboratory simulation experiment consisted of 100 percent polarlipid materials prior to contact with heated steel. After contact with hot steel the polarlipid material that did not combust or carbonize, decomposed to form aliphatic, olefinic and polarlipid materials in approximately equal quantities. Only the aliphatic portion of the volatilized solution was quantified, e.g., carbon chain lengths in the C-6 through C-19 range. Hydrocarbon com- pounds with chain lengths of this range are usually considered to be low in photochemical reactivity. However, no analysis was performed with respect to the volatilized portions' photochemical reactivity.

Only two types of rolling solutions were analyzed for chemical composition. Therefore, a general statement concerning all rolling oil volatilization characteristics is not possible. Rolling solutions used on cold mills are described on page 2-18.

The typical mill data were extrapolated to estimate the total hydrocarbon emissions from the steel industry as a whole. The total capacity for integrated steel companies in the United States is approximately 1.35 x 10^8 MT/year (148 x 10^8 tons/year). Estimates using the typical rolling mill hydrocarbon emission factor of 0.31 kg/MT (0.62 lb/ton) yield a yearly HC emission rate of 14,800 MT/yr (46,000 ton/yr).

Tables 7-1, 7-2, and 7-3 detail the data gathered from industry and actual source sampling. The final emission factor of 0.275 kg of volatilized hydrocarbons per metric ton of design capacity (0.55 lb/ton) can vary by a factor of plus or minus 50 percent. This is due to the fact that only two sampling tests were run and that both tests were conducted at the same steel mill facility. The hot strip mill emission factor of 0.037 kg/MT (0.074 lb/ton) can vary by as much as an order of magnitude. This high variability is due to three factors: (1) the mill actually sampled used no rolling oils at the time of the sampling; (2) the number of assumptions required to formulate an emission factor from the sampling data acquired; and (3) actual sampling data was available from only one hot strip rolling operation.

Table 7-3, Typical Plant Rolling Mill Emission Results, compiles the data gathered on individual rolling mills and constructs an emission factor based on the total production of an integrated steel mill. The emission factor of 0.31 kg per ton of steel produced (0.72 lb/ton) assumes each ton of steel sold requires one cold and one hot mill operation prior to sale. By using the equation:

$$nEF_{hot} + mEF_{cold} = EF_{rolling}$$

where:

n = number of hot rolling operations performed on a ton of steel (i.e., 1, 2, 3, . . .)

m = number of cold rolling operations performed on a ton of steel (i.e., 1, 2, 3, . . .)

EF = Emission Factor

The final emission factor can be refined for each steel facility. These typical plant rolling mill emission factors can vary as much as an order of magnitude since the data used for this calculation were based on preliminary results.

8.0 RECOMMENDATIONS FOR ADDITIONAL STUDY

During the course of the project, several areas were identified as potential subjects for additional study. This section provides a brief description of these topics. No attempt has been made to prioritize the various topics.

8.1 PHOTOCHEMICAL REACTIVITY OF VOLATILIZED LUBRICANTS IN VARIOUS ROLLING OPERATIONS

It was estimated that approximately 34,500 MT/yr (38,000 ton/yr) of volatilized hydrocarbons are emitted from rolling operations at domestic integrated steel facilities. More data are necessary to determine the photochemical reactivity of these emissions. Approximately nine formulations of rolling oils are commonly used in cold rolling operations today. The extent of the lubricant decomposition and the quantification of the volatilization rates are presently unknown. The evaluation of the impact of these emissions on the air quality (i.e., ozone formation) is a necessary second step in the investigation of volatilized lubricants. This study could also be expanded to include:

- Rolling operations: cold tandem, hot strip, tin, and other rolling mills
- Primary operations: slab, rail, billet, bar, and other primary mills
- Sintering: sintering mill

Detailed source testing could be implemented at each of these mills so that appropriate emission factors could be developed (for inclusion in AP-42) from the resulting test data. The data should be subdivided by specific operations in order to determine emissions from sources located in non-integrated mills.

Laboratory analysis would be performed after sampling to determine the photochemical reactivity of the resultant compounds. Representative samples of different lubricants used in rolling operations should be analyzed and categorized. Once the reactivity of the resultant emissions are quantified, the relative magnitude of steel plant hydrocarbon emissions in air sheds with recognized hydrocarbon/oxidant air quality problems should be determined. The fact that potentially significant hydrocarbon emissions are encountered in the steel industry (and nearly all steel plants are located in or near large population centers) necessitates this evaluation of steel mill hydrocarbon emissions. A more accurate estimate of steel plant hydrocarbon emissions, or some technically acceptable iron and steel industry hydrocarbon emission factors, would be very useful to federal, state, and local air quality planning and/or control agencies.

A review and evaluation of available hydrocarbon emission control technology is also necessary. The performance as well as the capital/operating/maintenance costs of such control equipment should be analyzed. The availability of a control system capable of minimizing air pollution emissions without resulting in additional water pollution or solid waste disposal problems should be evaluated. Control equipment vendors and users should be contacted for design, operation, and cost data. Growth predictions for the iron and steel industry, combined with the use of improved control technology and practices, should be used to project future steel industry hydrocarbon emissions.

8.2 HYDROCARBON EMISSIONS FROM SPECIFIC PROCESSES

8.2.1 CONTINUOUS CASTING

Potential hydrocarbon emissions from continuous casting operations may be as high, on a unit surface basis, as those for rolling operations. In this process, molten steel is first poured from a ladle into an intermediate pouring vessel called a tundish. The tundish is equipped with nozzles to feed the molds. Each mold is made out of copper and is internally water-cooled. Rolls pull down the starting bar which assists in pulling metal through the mold. The rate of metal flow is slow enough that the molten metal continuously solidifies into the desired form. The finished casting is further cooled by water sprays and is cut into desired lengths.

In many ways, this process is similar to conventional rolling operations. Tremendous amounts of lubricants are required to maintain the large numbers of moving parts. In some continuous casting operations, oil is injected into the copper mold to limit mold sticking. These lubricants may react in the same manner as those used in hot rolling operations. Also, the increased emphasis on wastewater recycling in continuous casting operations could lead to greater hydrocarbon emissions. Lubricants used on auxiliary equipment can become entrained in the slab recycle cooling water, and thereby volatilize when in contact with the hot metal.

8.2.2 HOT STRIP MILLS

It was estimated that a typical hot strip mill has a hydrocarbon emission factor of 0.052 kg/MT (0.104 lb/ton) annual capacity (design). This emission factor was developed without sampling data on mills which utilize rolling oils or wastewater recycling. It is necessary to quantify emissions from these mills for each of these conditions. The current trends in the steel industry are to increasing the use of rolling oils, and due to EPA water pollution control regulations, the implementation of total wastewater recycle systems. Rolling oils may increase the emission factor by as much as a factor of five, if the majority of lubricant used volatilizes rather than carbonizes or combusts. No estimate is presently available for the potential increase in hydrocarbon emissions due to wastewater recycling.

8.3 WASTEWATER SAMPLING AND OIL ANALYSIS

Sampling for oil content in water recycled to both cold and hot rolling operations is needed. An evaluation of present once-through systems to assimilate increased oil content in recycled wastewater blowdown would be a necessary first step, as recycled process water may contain higher levels of oil contamination than present wastewater effluents. This increased oil content could result in emissions which may significantly affect air quality problems from photochemical oxidants.

Wastewater sampling, analysis, and monitoring programs for total oil and grease content should be primarily experimental. Part of this experimental program should be to develop a repeatable sampling procedure and apparatus. The influence of sample apparatus parameters (such as the sinker weight and diameter, and the size of the sample jar mouth), and wastewater stream parameters (such as depth and stream velocity) must be evaluated. Once a repeatable sampling method is developed, a study to evaluate the representativeness of the grab sample to the actual wastewater stream should be undertaken. The frequency of grab sampling required to determine average wastewater oil and grease content must also be evaluated.

PES recommends a laboratory program to determine the accuracy and precision of the methods for total oil and grease analysis. Oil free industrial wastewater samples could be injected with known quantities of typical lubricating oils and grease, and then analyzed. Since steel plant wastewater discharges often contain from 0 to 500 mg/l of total oil and grease, the accuracy of the two analyses methods within this range should be evaluated.

An investigation of wastewater oil and grease sampling, and analysis methods should include a performance review from designers and users of the currently available continuous or portable monitors. Improved waste oil collection and recovery efforts are a growing trend in the steel industry. To meet increasing costs of virgin lubricants and stringent wastewater discharge regulations, more effective waste oil collection equipment and practices are being implemented at some steel facilities.

In addition, an economic analysis of these methods and the environmental problems associated with reclamation efforts could also be investigated using direct industry contact for review. Plant visits, equipment inspections, and discussions on operating practices would provide needed background information. Methods of reducing or controlling pollution discharge should be identified and described, along with their associated benefits and drawbacks.

9.0 REFERENCES

1. Institute for Iron and Steel Studies, Steel Industry in Brief, IISS, Green Brook, New Jersey, 1976.

2. Serne, J.C., and K. Wilson, The Use and Fate of Lubricants, Oils, Greases, and Hydraulic Fluids in the Iron and Steel Industry, May 1978, EPA-600/2-78-101.

3. McGannon, H.E., ed., The Making, Shaping, and Treating of Steel, Ninth Edition, United States Steel Corporation, Pittsburgh, 1971.

4. Patterson, James W., Wastewater Treatment Technology, Ann Arbor Science Publishers, Inc., 1975.

5. Chichelli, A.E., "The Steel Industry", in Standard Handbook of Lubrication Engineering, ed. by J.J. O'Connor, McGraw-Hill Book Company, New York, 1968.

6. Aarons, J.S., and C.A. Bailey, eds., The Lubrication Engineers Manual, First Edition, United States Steel Corporation, Pittsburgh, 1971.

7. Texaco, Inc., Steel Mill Lubrication, New York, 1973.

8. 40 CFR (Code of Federal Regulations) Protection of Environment, Parts 60 to 99, July 1976, pp. 75-80.

9. American Iron and Steel Institute, Directory of Iron and Steel Works of the United States and Canada, Thirty-fourth Edition, AISI, Washington, D.C., 1977.

10. Standard Recommended Practices for "Sampling Atmospheres for Analysis of Gases and Vapors", ASTM D 1605-60 (Reapproved 1973), pp. 469-490.

11. Quality of the Environment and the Iron and Steel Industry, -- Proceedings of a Conference by Commission of the European Communities, Pergamon Press, September 1974.

REFERENCES (Con't)

The following references, although not cited in the text, were reviewed and contain relevant information.

U.S. EPA, Effluent Guidelines Division, *Development Document for Interim Final Effluent Limitations Guidelines and Proposed New Source Performance Standards for the Forming, Finishing and Specialty Steel Segments of the Iron and Steel Manufacturing Point Source Category*, Volumes I and II, EPA-440/1-76/048-b, March 1976.

U.S. EPA, Effluent Guidelines Division, *Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Steel Making Segment of the Iron and Steel Manufacturing Point Source Category*, EPA-440/1-74-024a, June 1974.

U.S. EPA, Office of Technology Transfer, *Handbook for Monitoring Industrial Wastewater*, August 1973.

10.0 BIBLIOGRAPHY

Bishop, T. J., "Rolling Oil Practice for Tandem Cold Mills and Double Reduced Tin Plate," Iron and Steel Engineer Yearbook, 1968, pp. 747-749.

Cichelli, A. E., "Evaluation of Greases for Steel Mill Service," NLGI Spokesman, August 1973, pp. 160-173.

Dickinson, R. A., "Testing Cold Rolling Lubricants in the Laboratory," Iron and Steel Engineer Yearbook, United States Steel, 1968, pp. 749-760.

Donovan, Eugene J., Jr., "Treatment of Wastewater for Steel Cold Finishing Mills, Water and Wastes Engineering, November 1970, pp. F-22 to F.

Edmundson, M. R., "High Temperature Rolling Oils Aid Hot Rolling," Iron and Steel Engineer, October 1970, pp. 66-69.

Frazier, R., Sr., "Oil Mist Lubrication on Roll Neck Bearings," Iron and Steel Engineer Yearbook, 1963, pp. 576-580.

Gesdorf, E. J., "Recent Developments in the Design and Application of Centralized Grease Lubrication Systems," Iron and Steel Engineer, August 1974, pp. 65-70.

Globus, A. R., "A New High-Temperature Lubricant for Hot Rolling," Iron and Steel Engineer, August 1970, pp. 93-94.

Hostetter, R. S., "Increasing Hot Strip Mill Roll Life by Spray Lubrication," Iron and Steel Engineer, October 1973, pp. 66-70.

Musilli, Thomas, "Grease Eases the Way for Steel Mill Operations," Iron and Steel Engineer, March 1978, p. 30.

Nordstrom, R. P., Jr., "Ultrafiltration Removal of Soluble Oil," Pollution Engineering, Abcor, Inc., October 1974, pp. 46-47.

Rabosky, J. G., "Removing Oil From Plant Effluents," Plant Engineering, Colgon Corp., May 4, 1972, pp. 84-85.

Shamaiengar, M., "Cold Rolling Lubrication Technology," Iron and Steel Engineer Yearbook, 1967, pp. 381-387.

Simon, Richard, "Recirculation of Water in a Steelworks," Iron and Steel Engineer, December 1978, pp. 42-49.

U.S. Environmental Protection Agency, Iron and Steel Manufacturing Effluent Guidelines -- Forming, Finishing, and Specialty Steel, Volume I and II, Development Document EPA 440/1-76/048-b.

Vucich, M. G., "Emulsion Control and Oil Recovery on the Lubricating System of Double-Reduction Mills," Iron and Steel Engineer, December 1976, pp. 29-38.

Weymier, R. C., "Operation of Waste Water System at Inland's 80 Inch Hot Strip Mill," Iron and Steel Engineer Yearbook, 1968, pp. 183-193.

"World Steel in Figures--1978," Iron and Steel Engineer, August 1978, pp. 61-62.

APPENDIX A

TYPICAL LUBRICATING OILS USED
BY VARIOUS STEEL COMPANIES

1.0 EQUIPMENT UTILIZING LUBRICANTS, OILS, GREASES OR HYDRAULIC FLUIDS

Lubricant-type materials in the steel industry can generally be broken down as greases, lubricating oils, process oils, and hydraulic fluids. Due to the variety of operations and the amount and size of equipment used, no other industry employs a more complete usage of lubricants. High and low temperatures, shock loading, exposure to water, and abrasive materials are some of the adverse conditions normally encountered. All types of motors, turbines, bearings, gears, and drives must be properly lubricated to keep the machinery functioning.

Greases, oils, and hydraulic fluids are used in a multitude of purposes and locations in a modern integrated steel mill. A typical mill may have over 400,000 lubrication points using as many as 150 different specifications for lubricants. In the sections which follow, various classes of lubricants are listed together with types of equipment to which they are applied. For more detail in any specific area of the mill, Appendix A has a detailed breakdown by area and application point. A similar but more detailed steel mill lubrication guide is "A Practical Guide for Lubricating a Fully Integrated Steel Mill", by Joseph Lykins.

1.1 GREASES

Grease is generally used under the following conditions: 1) where there is no way to retain oil for the parts being lubricated; 2) when the lubricant must act as a seal to prevent the entrance of dirt; 3) when a lubricant is seldom added; and 4) where speeds are low and pressures are high.

The main use for grease is in the rolling mills. This includes both primary and secondary operations. The amount of machinery and extreme operating conditions demand a constant use of grease in many different situations. Steelmaking operations, as well as the blast furnace area, also account for large expenditure of this lubricant.

Typical greases used in the steel industry can be listed under the following generic categories:

- extreme pressure grease (EP)
- molybdenum disulfide grease
- roller bearing grease
- roll neck grease
- extra duty EP grease
- high temperature EP grease
- mill utility grease
- cup grease
- block grease

Extreme Pressure Grease - EP grease is used for normal operating temperatures of 66-93°C (150-200°F) on backup-roll, workroll, and table bearings; this includes conditions found on ball, roller, and plain bearings. EP grease is applied in situations where steel-to-steel contact is involved. One of the largest uses of EP grease is for various components of the finishing mills. This includes tensioning and coiler mandrels, roll bearings, and table bearings. Other uses are for the hot metal and slag cars, roll bearings on the continuous caster, and on the feeder and breaker in the sinter plant.

Molybdenum Disulfide Grease - Moly grease is used in slow-speed, plain-bearing, and sliding-surface applications operated under marginal lubrication conditions. General plant use of moly grease is limited. Specific applications are for the blast furnace hoist cables, BOF trunnion bearings, and open gears on the ore and limestone handling equipment.

Roller Bearing Grease - Roller bearing grease is a high-temperature multipurpose grease used for ball and roller bearing lubrication. It is commonly used in conditions covering exposure to water, high and low temperatures, shearing, oxidation, and rust. These conditions are encountered by bearings on electric motors, wheels, gear shafts, and conveyors. Applications include blast furnace motors, the tilting mechanism motor on the hot metal mixer, soaking pit door motors, and sinter machine couplings.

Roll Neck Grease - Roll neck grease is a mild EP grease used in the presence of large quantities of water. It is used in large amounts in the blooming mill, billet mill, slabbing mill, bar mill, and plate mill. It is typically used on the mill screwdown which is adjusted to control the height of the rollers.

Extra Duty EP Grease - Extra duty EP grease is used in locations where high operating temperatures are present (93-121^{o}C, i.e., 200-250^{o}F) and high pressure metal-to-metal contact is involved. Normal uses are on backup-roll, work-roll, and table bearings. It is applied to ball, roll, and plain bearings, and for general purpose lubrication in the presence of large quantities of water. These conditions are typically found on coke battery latches, bearings and rods, on the blast furnace distributor grease seals, and on the primary mill roll stands, table bearings and mill spindles.

High Temperature EP Grease - This is a high-temperature multi-purpose grease used as a ball and roller bearing lubricant. It is applied in a wide range of conditions such as, exposure to water, extreme temperatures, shearing, oxidation, rust and extreme pressure. These conditions are usually encountered by motor bearings, wheel bearings, heavy-duty mill bearings, and pressure systems requiring good mobility at low temperatures. Coke battery door hinges and latches, blast furnace torpedo cars, and electric-arc furnace electrode guides, drives, and latches are normal locations. The open-hearth furnace uses high temperature lubricants for charging box wheels. Reheating furnace doors, rollers, and rails also use large quantities of this grease.

Mill Utility Grease - Mill utility grease is used for operating conditions found on ball, roller, and plain bearings, including roll necks, and general purpose lubrication in the presence of large quantities of water where adherence to metal is important. A common use for this grease is the coke oven guides where large amounts of lubricant are needed.

Cup Grease - Cup Grease is used for the hand lubrication of plain bearings and bushings where the grease feed is controlled by a spring-load, screw-type, grease cup. Cup grease is widely applied to all types of small motors and machines in all parts of the plant.

Block Grease - Block grease is a water-resistant hand packed grease generally applied to rolling-mill necks. Since it is manually applied, it is generally used in older rolling mills having a minimum of automatic feed systems.

1.2 OILS

Oils are used in the steel industry for a wide variety of purposes. Very simply, oils are used in all cases where operating conditions do not dictate the use of a grease.

A basic list of common oils is given as below:

- engine oils
- extreme pressure oils (EP)
- R & O oils
- rolling oils
- Sendzimir mill rolling oil
- protective coating oil

Engine Oils - This category includes, gasoline engine oil, burbine oil, automatic transmission fluid, circulating oil, and diesel engine oil. These are all variable viscosity oils used for the lubrication of plain bearings, slides, machine tool bearings, low or normal load enclosed gears, and pistons and cylinders in engines. Common applications are in automotive engines, diesel locomotives, turbines, and power transmission systems.

Extreme Pressure (EP) Oils - Extreme pressure oils are used in applications involving high pressure metal-to-metal contact. These lubricants are applied to most gears unless they require grease lubrication. Examples are water pump gear drivers, blast furnace and crane reduction drives, rolling mill screw downs and shear drives, and rolling mill coiler and drives.

Rust and Oxidation Inhibited (R&O) Oils - These R&O oils are used in applications that require oil, but do not require EP characteristics. Frequently they are used in recirculating system. Typical applications are in plain Babbit, Mesta or Morgoil bearings in rolling mills, plain bearings in turbo blowers, air compressors and steam turbines, and in back-up roll bearings.

Rolling Oils - Rolling oils are not usually classified as lubricants, but they are used in large quantities in the cold processing of sheets, plates, strip steel or tin plate to reduce roll wear and improve the finish of the steel. These oils are specially formulated for each application and are not at all similar to lubricating oils. Some steel mills also use rolling oils in hot rolling operations.

Sendzimir Mill Rolling Oil - This is a low viscosity, oxidation and rust resistant oil. It is a well-refined oil designed for use in the Sendzimir Mills, which will serve the dual function of roll oil and lubricant for mill components. Different types of oils are used for different steels. Low viscosity mineral oil is used for heavy gauge, fatty polar types for stainless, paraffinic slushing oils for carbon and silicon, and palm oil for tin plate.

Protective Coating Oil - There are a wide variety of products that are used to protect finished products against corrosion, water, and extreme temperatures. Low viscosity mineral oils with polar additives and inhibited petroleum oils are commonly used for indoor storage. Heavy petroleum or asphaltic coatings and varnishes are used for outdoor applications.

1.3 HYDRAULIC FLUIDS

Hydraulic fluids are generally oil-based products and come in a slightly lesser variety than lubricating oils and greases. Some typical products in use include:

- inverted emulsions
- phosphate ester fluids
- water-glycol fluids
- inhibited hydraulic oil
- extra-duty anti-wear hydraulic oil

Inverted Emulsions - Inverted emulsions are stable water-in-oil emulsions used for fluid power systems that are subject to fire hazards. They are not suitable above 66°C (150°F), or above 10 megapascals (1500 psi), or in systems that are prone to shock loads or high shear stresses. They are the least expensive fire resistant hydraulic fluid. Inverted emulsion fluids are used in coke battery pushers, hot strip mill coil conveyors and the primary and secondary mill roll balance systems.

Phosphate Ester Fluids - Phosphate ester fluids are also used in hydraulic systems that are subject to fire hazards. They are suitable for high-pressure operating systems (to 34 megapascals) (500 psi) and high temperatures to 107°C (225°F). They are the most expensive type of fire resistant hydraulic fluid. A normal application is in the hydraulic systems of tractors used in the removal of pit slag. Optional uses are in the hydraulic systems on the scarfing machine, soaking pits, rotary furnaces, and askania regulators.

Water-Glycol Fluids - Water-glycol fluids are also used chiefly in areas subject to fire hazards. They are not suitable for power systems operating above 66°C (150°F) or above 14 megapascals (2000 psi). Typical uses are in the open-hearth dolomite machine, the electric-arc furnace tilting mechanism and electrode system, and the continuous caster pinch-roll and cut-off torch systems.

Anti-Wear Hydraulic Oil - Anti-wear hydraulic oils are normally used in all precision, stationary, hydraulic units, and where there is no fire hazard.

2.0 OILS, GREASES AND HYDRAULIC FLUIDS

The iron and steel industry uses a large number, frequently more than 100 different lubricants in the making, shaping, and treating of steel products. Different lubricants must perform under different conditions: at high temperatures, under high pressure, in the presence of water or steam, or they must be fire resistant.

The combination of requirements such as these determine the number and nature of lubricants that must be used. Frequently, the desired properties are acheived by using additives and a base lubricating stock. Approximately half of the lubricants produced in the United States are used in automobiles and 36 percent in industrial lubrication. Oil and grease consumption in the steel industry has been estimated at 378,500,000 liters (100,000,000 gallons) per year which represents three to five percent of the entire U. S. lubricant production.

In this chapter, oils, greases, and hydraulic fluids are discussed according to their chemical composition. The chemical composition of additives is also discussed and the toxicities of all materials are reviewed. A brief description of lubricant purchasing practices is provided at the end of the chapter.

2.1 CLASSIFICATION

Lubricants may be classified in two different ways: 1) according to lubricating characteristics; and 2) according to chemical composition. The former classification is most often used because it enables the lubrication engineer or maintenance worker to select the proper lubricant for the equipment that is being serviced. The latter classification is more useful in this study because the disposal, reclamation, and toxicity of a lubricant are determined by its chemical composition rather than by its viscosity, viscosity index and other physical properties. Both classification schemes are discussed below.

2.1.1 CLASSIFICATION ACCORDING TO LUBRICATING PROPERTIES

A typical classification scheme for steel mill lubricants is shown in Tables 3-1 and 3-2; 42 lubricating oil and 23 grease classifications

Table A-1. TYPICAL LUBRICATING OILS USED BY VARIOUS STEEL COMPANIES

Usual identity	Approx viscosity range, SUS at 100 F	General description	Recommended or preferred application	Number of companies reporting use
1. Spindle oil	Under 100	Turbine quality	Precision shop tools	1
2. Engine oil—low viscosity	Up to 450	Ordinary stability, water separation	Hand oiling, once-through sight feed	5
3. Engine oil—high viscosity	450/2,000	Ordinary stability, water separation	High loss hydraulic and circulating systems	1
4. Turbine oil	Under 500	High oxidation and rust resistant, water separation, top quality	Steam turbines, machine tools Precision hydraulic machines, motor rooms	5
5. Turbine and circulating oil	Under 500	Second-line turbine oil with good R and O and water-separating qualities	Ring-oiled bearings, circulating systems Lacking severe operating conditions	5
6. Circulating engine oil	Up to 2000	Good stability, water separation	High-loss circulating systems	3
7. Circulating oils	Over 500	Good stability, high-degree water separation	Backup roll oil-film bearings, enclosed gears	3
8. Black oil (at 210 F)	80–300	Asphaltic residual oil	Hand oiling, skids	4
9. Pale paraffin oil	....	Ordinary stability—pale oil	Slushing, flushing oil for systems	3
10. Cylinder oil—unfiltered	2,000 and up	Straight mineral, steam refined	Non-EP enclosed-gear lubricant, rough oiling	2
11. Cylinder oil—filtered	2,000 and up	Bright stock	Enclosed gearing where good quality desired	6
12. Cylinder—filtered, compounded	2,000 and up	Bright stock and acidless tallow	Steam cylinder lubrication—worm gearing	1
13. Cylinder—unfiltered, compounded	2,000 and up	Dark oil and acidless tallow	Steam cylinder lubrication—worm gearing	1
14. Motor oil—API, ML	150/1,250	Good stability	Automotive engines, air compressors, light service	2
15. Motor oil—API, MM	150/1,250	Good stability	Automotive engines, air compressors, medium service	2
16. Motor oil—API, MS	150/1,250	Good stability	Automotive engines, air compressors, severe service	3
17. Detergent diesel and motor—API, DG	150/1,250	Good stability and detergency	Diesel and automotive engines, light service	3
18. Detergent diesel (API-DM)	150/1,250	Good stability and detergency	Diesel and automotive engines, low-S fuel	2
19. Detergent diesel (API-DS)	150/1,250	Good stability and detergency	Diesel and automotive engines, high-S fuel	2
20. Caterpillar, Series 3	150/1,250	High stability and detergency	Caterpillar engines, high-S fuel	2
21. Diesel locomotive	....	EMD requirements	Locomotive service	3
22. Way lubricants	150/1,000	Compounded oil with good stick-slip	Machine tool ways	3
23. Hydraulic-slideway oils	150/300	Low-viscosity compounded oil with good stick-slip	Combination hydraulic and way oils—machine tools	1
24. Gear oil	500/4,500	Non-EP—SAE designations	Enclosed gearing	1
25. Hypoid gear oil	500/4,500	Active antiweld EP for high loading	Heavily loaded spiral bevel and hypoid gearing	3
26. Car journal oil	150/300	AAR requirements	Railroad-car journal bearings	3
27. Pneumatic tool oil	100/600	Wetting agent and emulsifier	Pneumatic tool cylinders	2
28. Light-duty mineral metalworking fluid	40/150	Fatty oil compounding	Used as required	2
29. Medium-duty mineral metalworking fluid	100/300	Low sulfur, low chlorine compounding		
30. Heavy-duty mineral metalworking fluid	150/500	Active sulfur, high S, high Cl compounding		3
31. Conventional soluble oil	100/1,500	Emulsifier, rust inhibitor, low activity		4
32. Heavy-duty soluble oil	150/2,350	Emulsifier, rust inhibitor, S, Cl, or fats added		4
33. Chemical cutting fluid	Various	Synthetic, usually water soluble		1
34. Extreme-pressure gear oil	300/17,000	High load-carrying capacity, good stability, water separation	Mill drives, pinions, screws, and nuts	7
35. Roll-neck spray oil	300/1,000	Same as gear oil, plus adhesiveness in presence of water	Roll-neck bearings, gearing	2
36. Open-gear lubricant (non-EP)	750 at 210 F up	Normal temp; shock resistant, water resistant	Open gearing, chains, skids	3
37. Open-gear lubricant (EP)	750 at 210 F up	Adhesive, high load capacity, water resistant	Heavily loaded open gearing, chains, etc.	3
38. Hydraulic (inverted emulsion)	200/450	Nonseparating, low cold test, fire resistant	Specified by type of pump	2
39. Hydraulic (water glycols)	150/300	Fire resistant, good wear resistance	Specified by type of pump	3
40. Hydraulic (phosphate ester types)	90/250	Fire resistant, good wear resistance	Specified by type of pump	2
41. Antiwear hydraulic oil	Under 500	Inhibited oil with antiwear additives	High-pressure hydraulic service specified by pump	4
42. Mist oils	150/1,500	Good misting, non-gumming	High-speed antifriction bearings	4

SUS = Saybolt Universal Seconds: Viscosity conversion tables are available in chemistry or lubrication handbooks.

Table A-2 TYPICAL LUBRICATING GREASES AND COMPOUNDS USED BY VARIOUS STEEL COMPANIES

Usual identity	Pertinent information	General requirements	Recommended or preferred application	Number of companies reporting use
1. Asphaltic/residual base—EP	6,000 at 100 F	Various soap gelling agents plus asphaltic oil	Couplings, screwdowns, cables	1
2. Block grease—non-EP	Usually Ca soap	NLGI-4 to 6½, 200 at 350 F mp (no lead or graphite)	Roll-neck lubrication for hand-packed design	3
3. Block grease—EP	Usually Ca soap	NLGI-4 to 6½, 200 at 350 F mp with lead or graphite	Heavily loaded roll necks, old hand-packed design	3
4. Cup grease—light duty	Oil viscosity under 400 SSU	Normal temp, water resistant	Light loads, general grease-cup lubrication	3
5. Cup grease—heavy duty	Oil viscosity over 400 SSU	Normal temp, water resistant	Medium loads, general grease-system lubrication	2
6. General purpose—stringy	Stringiness added	Ca soap, normal temp, water resistant, elastomer	Centralized systems, where stringiness desired	1
7. Graphited roll-neck grease	Oil viscosity 1,000 at 100 F	Ca soap, medium temp, water resistant	Roll-neck bearings, centralized grease systems	3
8. High-temp graphited roll-neck grease	Oil viscosity 1,000 at 100 F	Sodium soap, graphite, for high operating temp	Roll-neck bearings, system grease—bronze slippers	2
9. Standard EP roll-neck grease	Oil viscosity 1,000 at 100 F	Ca soap, leaded, water resistant	Heavily loaded table roller or plain bearings and roll-neck bearings	7 1
10. Standard non-EP roll-neck grease	Oil viscosity 1,000 at 100 F	Similar to cup grease heavy duty, heavy base oil, no EP	Roll-neck bearings, wire rope	2
11. Extreme temp EP	Calcium complex Aluminum complex	Dropping point (500 F) EP, water resistant	High, continuous operating temp over 250 F	5
12. Inert base	Non-soap gelling	No dropping point, water resistant	High, continuous operating temp over 250 F	3
13. Inert base EP	Non-soap gelling	Same, but leaded for extreme pressures	Same but for high loads	1
14. Extra duty	Lithium soap	High temp, water resistant, mechanically stable	Antifriction and plain bearings (150–250 F)	2
15. Extra duty EP	Lithium soap	High temp, water resistant, EP	Same but for high loads	6
16. Ball and roller bearing grease	Mixed base	Fibrous, medium temp, oxidation and shear stability	Antifriction bearings	3
17. Mining machine lubricant	Calcium soap	Semifluid, multipurpose, water resistant, EP	Mining machine gears and bearings	2
18. Car journal grease	Calcium soap	Semifluid, water resistant, wool yarn horsehair	Journals designed for grease packing	2
19. Drawing and forging	Various	Semifluid with high graphite and/or fat	Forging compounds	1
20. Petrolatum	....	100–130 F mp	Slushing, rope lubrication, rust prevention	2
21. Pipe thread grease	API specifications	Prevent leakage in API casing and tubing joints, zinc, graphite, etc., filler	Pipe threads and couplings	2
22. Roller bearing grease	Sodium base	Fibrous, high temp, non-water-resistant	Antifriction bearings, no water presence	5
23. Moly grease	MoS_2 filler	3 to 10% MoS_2, in various soap greases	Oscillating, highly loaded bearings, some gearing	3

Saybolt Universal Seconds: Viscosity conversion tables are available in chemistry or lubrication handbooks.

Table A-3 LUBRICANT CONSOLIDATION PROGRAM

Basic Performance Classification

The number assigned to these requirements have been established for identification within U. S. Steel and have no significance outside of U. S. Steel.

USS REQ. NO.	COMMON IDENTIFICATION
080	Diesel Fuel
081	Diesel Fuel No. 2 — Convertol
085	Coke Plant Wash Oil
110	Engine Oil
116	Non-Inhibited Hydraulic Oil
119	Unclassified
120	Turbine Oil
122	Ford Type F
123	Auto. Transmission Fluid, Dexron
124	Hydraulic Transmission Fluid, Type C-12
125	Circulating Turbine Oil
126	Inhibited Hydraulic Oil
129	Unclassified
130	Circulating Engine Oil
133	Elastomer Oil
134	Way Lubricant
135	Circulating Oil
136	Extra Duty Circulating Oil
139	Unclassified
140	API Service CA
141	API Service CA
142	API Service CB
143	API Service CC
144	API Service CC
145	API Service CC
146	Caterpillar Series 3
148	Locomotive Diesel Engine Oil
149	Unclassified
150	Pale Paraffin Slushing Oil
151	Sendzimir Mill Rolling Oil
152	Compounded Quenching Oil
153	Compounded Rust Preventative
154	Coal Spray Oil
159	Unclassified
160	Mineral Metalworking Fluid
161	Hvy. Duty Min. Metalworking Fl.
162	Soluble Metalworking Fluid
163	Hvy. Duty Sol. Metalworking Fl.
167	Water Hydraulic Additive
168	F. R. Fluid Invert Emulsion
169	Unclassified
170	F. R. Fluid Phosphate Ester
171	F. R. Fluid Glycol-Water Base
174	Heavy Duty Brake Fluid
175	Synthetic-Petroleum Hydraulic Fluid
179	Unclassified
190	Insulating Oil
191	Penetrating Oil
196	Pneumatic Tool Oil
199	Miscellaneous Oil Unclassified
200	Cylinder Stock Oil
209	Unclassified
210	Compounded Cylinder Oil
211	Cylinder Oil (Less than 5% ATO)
219	Oil Unclassified
220	Extreme Pressure Oil
221	Hypoid Gear Oil
222	Extra Duty Gear Oil
225	E. P. Open Gear Compound
226	E. P. Solvent Cut-Back Open Gear Compound
227	Dipper Handle Lube
229	Unclassified
230	Black Oil
233	AAR Car Oil
235	Open Gear Compound
236	Solvent Cut-Back Open Gear Compound
239	Unclassified
299	Special Oil Unclassified
300	Cup Gr. (100 to 400 SSU @ 100F)
301	Cup Gr. (400 to Cyl. Stock @ 100F)
309	Unclassified
310	Sodium Base Roller Brg. Grease
319	Unclassified
330	Mixed Base Roller Brg. Grease
339	Unclassified
340	Graphited Roll Neck Grease
343	Heavier Than Water Grease
346	Molly Grease
349	Unclassified
350	Extreme Pressure Grease
352	Extra Duty E. P. Grease
355	Extreme Temperature E. P. Grease
359	Unclassified
370	High Temperature E. P. Grease
371	Ball & Roller Bearing Grease
372	Extreme Temperature Grease
373	Mining Machine Lubricant
374	AAR Journal Roller Bearing Grease
375	Mill Utility Grease
379	Unclassified
400	Block Grease
405	General Hoisting Heavy Gauge Wire Lub.
406	General Hoisting Light Gauge Wire Lub.
409	Unclassified
410	Impregnated Journal Compound
411	Replenishing Lubricant
490	Thread Compound — API Modified
491	Thread Compound — API Silicone
498	Petrolatum
499	Special Grease Unclassified
800	Asphalt Road Oil, Work Oil, Grade Oil, etc.

Table A-4 INDEX TO STANDARD SPECIFICATIONS FOR LUBRICANTS

KSC SPEC NO.	TITLE
60000	MULTI-PURPOSE E.P. WATER-PROOF MOLY GREASE
60001	MILL GREASE, WASH RESISTANT
60002	MILL GREASE, MULTI-PURPOSE
60003	GREASE, BALL & ROLLER BEARING, LIGHT
60004	MILL GREASE, MOLYDISULFIDE
60005	MILL GREASE, MOLY SPINDLE LUBE
60006	MILL GEAR GREASE, FLUID
60007	LOW TEMP. G.P. GREASE
60010	E.P. WATER-PROOF GREASE
60050	GREASE, BALL & ROLLER BEARING
60051	GREASE, HIGH TEMPERATURE
60056	GREASE, HIGH TEMPERATURE (PRECISION MACHINERY)
60100	OPEN GEAR LUBRICANT, DILUTED
60103	OPEN GEAR LUBRICANT, LIGHT
60105	OPEN GEAR LUBRICANT, HEAVY
60106	OPEN GEAR LUBRICANT, X-HEAVY
60108	OPEN GEAR LUBRICANT, ULTRA-HEAVY
60109	MOLY CHAIN OIL & WIRE ROPE DRESSING
60200	NON-LEAD E.P. INDUSTRIAL GEAR OIL, LIGHT
60201	NON-LEAD E.P. INDUSTRIAL GEAR OIL, MEDIUM
60202	NON-LEAD E.P. INDUSTRIAL GEAR OIL, HEAVY
60203	NON-LEAD E.P. INDUSTRIAL GEAR OIL, X-HEAVY
60204	NON-LEAD E.P. INDUSTRIAL GEAR OIL, ULTRA-HEAVY
60205	NON-LEAD E.P. INDUSTRIAL GEAR OIL, X-LIGHT

KSC SPEC NO.	TITLE
60249	MULTI-PURPOSE E.P. GEAR OIL SAE-80
60250	MULTI-PURPOSE E.P. GEAR OIL SAE-90
60251	MULTI-PURPOSE E.P. GEAR OIL SAE-140
60300	MORGOIL OIL - MEDIUM
60301	MORGOIL OIL - HEAVY
60305	BEARING OIL - HEAVY (MIST)
60360	CYLINDER OIL - MEDIUM
60400	HYDRAULIC OIL, A.W. LIGHT
60401	HYDRAULIC OIL, A.W. MEDIUM
60402	HYDRAULIC OIL, ASKANIA
60403	HYDRAULIC OIL A.W. LOW TEMPERATURE
60450	HYDRAULIC FLUID - WATER GLYCOL
60460	HYDRAULIC FLUID - INVERT EMULSION
60500	TURBINE OIL, LIGHT
60501	TURBINE OIL, MEDIUM
60502	TURBINE OIL, MEDIUM HEAVY
60503	TURBINE OIL, HEAVY
60550	AIR COMPRESSOR OIL, MEDIUM
60581	MOTOR OIL SAE 10W/30
60582	MOTOR OIL SAE 20W/40
60600	MOTOR OIL, HD, SAE-10W
60601	MOTOR OIL, HD, SAE-20W/20
60602	MOTOR OIL, HD, SAE-30

KSC SPEC NO.	TITLE
60603	MOTOR OIL, HD, SAE-40
60604	MOTOR OIL, HD, SAE-50
60605	RAILROAD OIL, SAE-40
60650	MOTOR OIL, S-3, SAE-10W
60651	MOTOR OIL, S-3, SAE-20W/20
60652	MOTOR OIL, S-3, SAE-30
60653	MOTOR OIL, S-3, SAE-40
60680	AUTOMATIC TRANSMISSION & TORQUE CONVERTER FLUID (DEXRON-II)
60681	AUTOMATIC TRANSMISSION FLUID TYPE F (2-P)
60682	HYDRAULIC TRANSMISSION FLUID-TYPE C-2
60700	CUTTING OIL, TRANSPARENT
60701	CUTTING OIL, DARK
60750	SOLUBLE OIL
60751	SOLUTION OIL, E.P.
60752	WATER-BASE CHEMICAL GRINDING COOLANT
60754	CONVEYOR SPRAY OIL
60755	WATER EXTENDABLE SYNTHETIC GRINDING COOLANT
60783	HYDRAULIC BRAKE FLUID
60800	JOURNAL OIL, HEAVY
60801	MILL OIL, HEAVY
60802	E.P. WAY OIL, LIGHT
60803	E.P. WAY OIL, HEAVY
60804	JOURNAL OIL, LIGHT
60809	ROCK DRILL OIL, E.P.

are shown along with the pertinent characteristics of each. Viscosity, resistance to oxidation, water separation, detergency, performance at extreme pressures and temperatures, and price of the lubricant are major factors that define each category. Categories are given names such as circulating engine oil, hypoid gear oil, general purpose grease, and anti-wear hydraulic oil, etc. that are helpful in describing families of lubricants. Within each of these categories several specific lubricants are usually manufactured in a range of viscosities or other properties. The same types of lubricants may be available from several manufacturers.

The categories as listed in Tables A-1 and A-2 are too general to be useful to someone who wants to select the correct lubricant for a particular piece of equipment or for a purchasing agent who must replenish stocks of lubricants. For this latter purpose steel mills have assigned identification numbers or classification numbers that are used internally as a means of identifying each individual lubricant. Examples of such schemes are given in Tables A-3 and A-4. Table A-3 shows the United States Steel Corporation classification which uses a three-digit requirement number to identify each of 101 different lubricants. United States Steel publishes the Lubrication Engineers Manual that lists the lubricant performance requirements corresponding to each requirement number, and gives directions for performing tests to see if specifications are met. The Kaiser Steel Corporation lubricant index is also presented in Table A-4. Kaiser Steel maintains detailed listings stating the physical properties, performance requirements, types of containers, and container labeling schemes for each of the 93 lubricants in this list. Youngstown Sheet Tube uses approximately 120 different lubricants which are broken down into 36 basic specifications and are obtained from 20 different suppliers. Other steel mills have similar requirements and procedures.

Although most steel mills have their own classification schemes, all schemes have much in common. Lubricants are generally identified and classified by similarities in their performance specifications, chemical or physical properties, or types of service. Indexes or classification lists are used internally as a means of identifying lubricants. Code numbers are assigned enabling more efficient and simplified procurement, storage, handling and record keeping. Lubricant application charts and schedules typically incorporate the code scheme. The classification of lubricants by code number enables lubrication engineers and plant operators to readily identify duplication of brand name products. Records of lubricant purchase and/or application are frequently maintained in computers, and code numbers are used for these records. Delivery of lubricants in containers color coded and labeled only by the steel mill's code number is often required. This procedure may avoid certain plant operator biases toward a given brand or trade name product.

Some steel mills may use more types of lubricants than are really essential, since equivalent results may be obtained with several different lubricants. Other mills have made efforts to consolidate and simplify their lubricant usage whenever possible. Making changes in lubricant recommendations on major producing units is generally a slow process. The underlying reasons are traditional conservatism (experimentation and experimental mistakes may be costly), divided responsibility in some cases (different departments are often responsible for the selection, purchase and application of lubricants), and reluctance to experiment where mill performance appears to be adequate with the existing lubricant. Nevertheless, interest toward consolidation of lubricants has brought multipurpose lubricants into favor in most steel mills. The trend has been towards centralized and automatic lubricant application systems which, if designed and maintained properly, can simplify lubrication efforts. Although consolidation of lubricants may result in an upgrading of specifications or properties, especially where greases are concerned, and a resulting higher average cost per gallon or pound of lubricant purchased; these increased costs are often offset by other savings, such as reduced lubricant purchase, storage, and handling requirements.

2.1.2 CLASSIFICATION ACCORDING TO CHEMICAL CONSTITUTION

The average lubrication engineer at a steel mill has little use for a classification scheme based on the chemical composition of the lubricant. However, for this study, such a scheme is useful because it relates to the ultimate fate of these lubricants and to the toxicities of the end products. By far, the greatest quantities of lubricants -- 97% of the worldwide total -- are derived from petroleum. Petroleum is, of course, a mixture of hundreds of different hydrocarbons along with small amounts of compounds that contain nitrogen, sulfur, oxygen, and certain metals. Table A-5 shows how the relative quantities of the various components affect the properties of the lubricant.

The exact composition of the base oil depends on the oil field where it was produced, but these differences are usually small (see Table A-6). Base oils are subjected to various refining processes to alter their properties, usually by removing some minor components of the base oil. However, all petroleum-based lubricants are sufficiently similar with respect to their chemical composition that they can be treated as a single class for the purpose of this discussion.

A suggested classification scheme based on the chemical composition of the base oil is given below.

A. Petroleum-based

B. Non-petroleum based

  1. Natural oils

    a. Tallow
    b. Vegetable oils

  2. Synthetic lubricants

    a. Phosphate esters
    b. Glycols
    c. Others

Most of the natural oils are mixtures of closely related substances, for present purposes they can be treated as single classes. The synthetic lubricants, on the other hand, are usually single chemical species, and the various subclasses of synthetic lubricants differ widely.

In a typical steel mill, synthetic lubricants may be used as fire-resistant hydraulic fluids, and natural oils are used in large quantities as rolling oils at all steel mills that produce sheet and tin plate. All other lubricants, hydraulic fluids and process oils used by a steel mill

Table A-5 BASE OIL COMPOSITION AND DEPENDENT PROPERTIES

Component	Properties affected by presence in oil
Hydrocarbons: Paraffins Naphthenes Aromatics	Bulk properties such as -- Viscosity, V.I. Gravity Pour point Aniline point Unsulfonated residue Solvency Oxidation: Stability and response to antioxidants Volatility Response to V.I. improvers
Nonhydrocarbon: Nitrogen compounds Sulfur compounds Oxygen compounds Organometallic compounds	Oxidation: Stability and response to antioxidants Demulsibility Lubricity Solvency EP properties Foaming Rusting

Table A-6 COMPOSITION ANALYSIS

Type of compound	California paraffinic 480 neutral 90 V.I.	Hydro-treated 500 neutral 101 V.I.	MC paraffinic 350 neutral 97 V.I.
n-d-M analysis:			
Percent carbon atoms in aromatic rings	5.5	3.5	2
Percent carbon atoms in naphthene rings	32	26.5	33
Percent carbon atoms in paraffin chains	62.5	70	65
Mass spectrometer analysis (volume percent):			
Paraffins	11.5	14.8	13.9
Cycloparaffins:			
1 ring	19.4	19.6	15.9
2 rings	11.3	19.7	18.0
3 rings	15.6	11.9	14.6
4 rings	15.3	6.7	10.5
5 rings	10.6	8.2	11.6
6 rings	0	0	0
Alkylbenzenes	4.8	7.5	5.7
Indanes-tetralins	2.6	2.8	1.7
Benzodicycloparaffins	2.7	2.3	2.4
Naphthalenes	.7	.6	.5
Acenaphthenes	.6	.5	.2
Fluorenes	0	0	0
Phenanthrenes	1.1	1.8	.9
Pyrenes	1.1	1.3	.7
Chrysenes	2.3	1.8	2.7
Benzothiophenes	.3	0	.2
Dibenzothiophenes	.1	.5	.5
Naphthobenzothiophenes	0	0	0
Summary:			
Paraffins	11.5	14.8	13.9
Cycloparaffins	72.2	66.1	70.6
(3 rings and larger)	(41.5)	(26.8)	(36.7)
Aromatics	15.9	18.6	14.8
(3 aromatic rings and larger)	(5.1)	(5.4)	(4.5)
Thiophenes	.4	.5	.7
Total saturates	83.7	80.9	84.5

V.I. = Viscosity Index - an empirical number indicating the rate of change in viscosity of an oil within a given temperature range.

are petroleum-based products.

2.2 ADDITIVES

An additive can be defined as a substance that reinforces some desirable property already possessed to some degree by the oil, or imparts a new and desirable property not originally present. Although several hundred materials have been developed as additives, their principal functions can be grouped into eight categories:

- reduce oxidative degradation of lubricant
- lessen deposition of harmful deposits
- minimize rust and corrosion
- control frictional properties
- reduce wear
- prevent destructive metal-to-metal contact
- alter viscosity or viscosity index
- reduce tendency to form stable foams

In the trade, a group of descriptive terms is used to identify additives and approximately describe their use. For example, antioxidant, corrosion inhibitor, rust inhibitor, extreme pressure (EP) agent, antistain agent, antifoam agent, antiwear agent, V.I. improver, and detergent are all commonly used terms. Some additives have more than one function, so it is not possible to identify specific additives from these descriptive terms, but Table A-7 gives a listing of additives used in steel mill lubricants, and their functions.

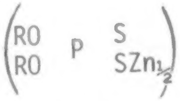
Additive formulations are usually patented, and lubricant manufacturers consider their particular formulas to be proprietary. Nevertheless, certain general facts are available regarding additive composition and usage. The specific chemical compositions of the most widely used additives are given below.

Lithium-12-hydroxy stearate is used as a thickening agent in most steel mill greases in quantities averaging about six percent of the total weight of the grease. In most steel mills, this additive is used in greater quantity than any other additive. Molybdenum disulfide is used in addition to lithium-12-hydroxy stearate in certain greases for oscillating mechanisms and highly loaded bearings. It is added in quantities up to

Table A-7. TYPES OF STEEL MILL LUBRICANTS AND THE ADDITIVES THEY MAY CONTAIN

Steel Mill Lubricants	Amount of Lubricant Used	Type of Additive	Purpose of Additive	Types of Compounds Used
GREASES				
Extreme Pressure (EP)	moderate	thickener	improve consistency	calcium or lithium soaps
		EP agent	prevent welding and galling at high pressure	sulfur, phosphorus compounds, sometimes lead compounds
		antioxidant	prevent oxidative degredation	organic cpds. usually containing sulfur, phosphorus or nitrogen
		corrosion inhibitor	minimize rust and corrosion	organic cpds. of many kinds
Molybdenum Disulfide	small	same as for EP grease plus another EP agent	prevent welding and galling during high pressure, slow speed applications	same as for EP grease plus molybdenum disulfide
Roller Bearing	moderate	thickener	improve consistency	calcium or lithium soaps
		antioxidant	prevent oxidative degredation	organic cpds. usually containing sulfur, phosphorus or nitrogen
		corrosion inhibitor	minimize rust and corrosion	organic cpds. of many kinds
High Temperature	small	thickener	improve consistency	bentomite, lithium or aluminum soaps
		EP agent (optional)	prevent welding and galling at high pressure	organic compounds containing sulfur or phosphorus
Cup	very small	thickener	improve consistency	calcium soap
		graphite	assist in lubrication	graphite
OILS				
Engine	small	pour depressant	permit easy cold weather starting	organic polymers
		Viscosity Index improver	maintain good lubricant film at high temperatures	organic polymers
		anti-foam compound	minimize foaming	silicone polymers
		detergent	keep engines clean	soaps of alkyl phenates, sulfonates and phosphonates
		antioxidant	prevent oxidative degredation	organic cpds. usually containing sulfur, phosphorus or nitrogen
		corrosion inhibitor	prevent bearing corrosion	organic cpds. of many kinds
		dispersants	prevent sludge accumulation	high molecular weight alkyl succinimides and thiophosphonates
		EP (anti wear) agent	prevent excessive wear and scuffing of valve train	zinc dialkyldithiophosphate
Extreme Pressure (EP)	large	anti-foam compound	minimize foaming	silicone polymers
		antioxidant	prevent oxidative degredation	organic cpds. usually containing sulfur, phosphorus or nitrogen
		corrosion inhibitor	minimize rust and corrosion	organic cpds. of many kinds
		rust inhibitor	prevent rust of metal parts	sulfonates, amines, phosphates, certain acid derivatives
		EP agent	prevent welding and galling at high pressure	organic compounds containing sulfur or phosphorus
Rolling Oils	very large	no additives		
Protective Coating	variable	rust inhibitor	prevent rust of metal parts	sulfonates, amines, phosphates, certain acid derivatives
HYDRAULIC FLUIDS				
Inverted Emulsion	moderate	no additives		
Water-Glycol	small	no additives		
Anti-wear	moderate	same as engine oils without detergents	(see under "Engine Oils" above)	(see under "Engine Oils" above)

four or five percent by weight to form specialty greases that constitute 10 to 30 percent of the total grease consumption in typical steel mills. Some high temperature greases contain clays such as bentonite or calcium soaps in place of the lithium-12-hydroxy stearate as a thickener. These greases are usually used in small quantities in various operations associated with iron and steel production. Greases for extreme pressure applications contain sulfurized and phosphorized fatty oils in quantities equivalent to .03 percent phosphorus and .8 percent sulfur in the grease. Extreme pressure greases usually constitute 30 or 40 percent of the total greases used in a steel mill.

Zinc dialkyl dithio phosphate  $\left(\begin{matrix}RO\\RO\end{matrix}\ P\ \begin{matrix}S\\SZn_{\frac{1}{2}}\end{matrix}\right)$ is widely used in oils as a mild EP additive and corrosion inhibitor in amounts averaging .8 percent by weight. In most steel mills, this additive ranks second with respect to total quantity used -- outranked only by lithium-12-hydroxy stearate. It also functions as an antioxidant, but a small percentage of oils contain 2,6-di-t-butyl-4-methyl phenol (BHT) instead.

Oils for extreme pressure use contain the same kinds of quantities of extreme pressure additives that were mentioned in the paragraph above dealing with greases. Lead naphthenate was formerly used as an extreme pressure additive, but it is being phased out because of poor stability to heat and oxidation, as well as its adverse environmental impact. Some lead naphthenate gear oils are still in use in mills where there is reluctance to abandon a lubricant that has performed satisfactorily in the past, but most lubrication engineers believe that nonleaded gear oils can be used with equivalent or superior results.

Other kinds of additives such as rust inhibitors, V.I. improvers, antifoam compounds, detergents, and dispersants are used in extremely small quantities in the steel industry. As will be shown in Section 9, the usage of these minor additives is so small that no material balance study was done for each of them.

In general, lubricants, process oils, and hydraulic fluids that are not petroleum-based do not contain additives. Rolling oils, which are used in large quantities in cold rolling operations, are derived from palm oil, tallow, or other fatty materials and normally require no additives. Fire resistant hydraulic fluids of certain types are also used without additives. Most, but not all, petroleum-based lubricants do contain additives.

2.3 TOXIC SUBSTANCES

Before an attempt is made to classify lubricants and their additives, as toxic or nontoxic substances, it is necessary to clarify the meaning of the term "toxic". Substances may be harmless or even beneficial to man and yet be hazardous to fish and other marine life. Other substances may be harmful when they enter the body via the respiratory system, but harmless when taken in via the gastro-intestinal tract. Some materials produce acute effects that disappear completely when the exposure ceases, while the effects of exposure to other materials may require many years to become evident. For purposes of this discussion, substances are classified as toxic whenever they meet any of the criteria for defining toxicity used by EPA, the National Institute for Occupational Safety and Health (OSHA), the Food and Drug Administration, and other agencies. The most useful criteria are those used by EPA for designating hazardous air pollutants, the OSHA list of cancer-suspect materials, the EPA list of 306 materials that may be hazardous in natural waters, and the list of substances permitted for use as foods, food additives, drugs, cosmetics, or packaging materials according to the Federal Food, Drug and Cosmetic Act.

2.3.1 TOXICITIES OF LUBRICANT BASE OILS

Most lubricants used in steel mills are petroleum-based and present the same toxicological problems as petroleum-based materials used for other purposes. (The toxicities of additives are discussed in the next section.) Extensive investigations have been conducted on these materials because of their widespread use, and until recently, they were classified as nontoxic. However, benzene which is a minor component of petroleum has now been placed on the EPA list of hazardous air pollutants. Benzene is a low boiling material which is presently primarily in gasoline and is entirely absent from the higher boiler lubricating oils. It is conceivable that traces of benzene might be associated with cut-back gear lubricants. Petroleum-based lubricants are troublesome in the water supply because they form oil films that are not pleasing aesthetically and have adverse effects on fish and water fowl. When lubricating oils are burned or otherwise subjected to very high temperatures, they may emit polynuclear organic compounds such as benz-x-pyrene that are known to be carcinogens. This phenomenon has been demonstrated many times in studies on oil-fired boilers and similar combustion processes. In the iron and steel industry, lubricants may encounter high temperatures at the sinter plant and during heavy duty applications. It is conceivable that polynuclear organics could be emitted at these locations.

In this discussion we must also consider the non-petroleum based lubricants. Vegetable oils and tallow are used in large quantities as process oils in the steel industry. These materials are found in natural meat and vegetable foods and present no hazards to humans, nor are they listed as hazards in natural waters. They form oil films when discharged into wastewater with the same adverse effects as oil films from petroleum products. Glycols that are used in fire resistant hydraulic fluids do not present any special problems of toxicity. These same materials are used in much larger quantities for other applications, such as anti-freeze, and do not require any special investigation in conjunction with their use in the steel industry. The toxicities of phosphate esters that are used as fire resistant hydraulic fluids are somewhat uncertain. Phosphate esters are not specifically included on any of the lists of toxic substances, but several other phosphorus-containing compounds are included. Further investigation might be appropriate to determine whether phosphate esters have ever been subjected to toxicological investigation and found to be harmless, or whether they have never been tested at all. Fortunately, they are used in small quantities in steel making because of their high cost.

2.3.2 TOXICITIES OF LUBRICANT ADDITIVES

None of the materials commonly used as lubricant additives are specifically included on any list of toxic substances; however, this does not mean that they have all been tested and found harmless. Many additives are unusual compounds that have no other uses and may never have come under scrutiny because of their proprietary nature. Presumably, they will be included in the inventory of chemical substances which is currently being compiled to meet the requirements of the Toxic Substances Control Act, and conceivably, some of them could be designated as high-priority test candidates.

The following list gives lubricant additives, in the approximate order of usage in a typical steel mill, along with comments about their possible toxicity. Quantitative estimates of usages and the ultimate fates of these additives are discussed in EPA Publication #600/2-78-101.

1. Lithium-12-hydroxy stearate - Lithium compounds are not generally considered toxic nor are stearic acid derivatives. There is no reason to assume that this particular compound is toxic.

2. Molybdenum disulfide - This material has low volatility and is insoluble in water. According to the Merck Index "limited data suggest a low order of (human) toxicity".

3. Zinc dialkyl dithiophosphate - Many zinc compounds are biologically active, and are used as fungicides, antiseptics, and astringents. Dialkyl dithiophosphates do not appear to have been tested, or if they have been, the results were not published. This material probably should be investigated further.

4. Sulfurized and Phosphorized fatty oils - These are proprietary materials of uncertain composition. The parent fatty oils are not toxic, but it is uncertain whether any toxic properties result from the sulfurizing and phosphorizing treatments.

5. BHT (2,6-di-t-butyl-4-methly phenol) - This material is approved for use as an antioxidant in food products and is nontoxic to humans.

6. Lead naphthenate - Lead compounds are generally classified as poisonous and naphthenic acid derivatives are considered hazardous. Fortunately, this additive is being phased out, it is unquestionably a toxic material.

A recent publication has called attention to the presence of a toxic nitrosamine in synthetic cutting fluids that contain triethanolamine.

Cutting fluids of this type are not used in steel mills according to the information collected for this study, so these toxic nitrosamines are not a problem in the steel industry.

Polychlorinated biphenyls (PCB's) have been reported in fire resistant hydraulic fluids that are sent by Republic Steel to a reclaimer (Radco Industries). These materials are know to be toxic and are being phased out of all industrial usage. PCB's are not used as lubricants, nor are they purchased by the lubrication departments of steel mills. They may be used in electrical transformers, or other specialized equipment found at steel mills, but they should not contaminate lubricants except as a result of infrequent accidental incidents.

2.4 PURCHASING PRACTICES

The lubricant purchasing practices followed by the steel mills surveyed are described in this section. Two different practices or policies are generally followed with either reported to function satisfactorily. Many steel mills "buy by requirement", whereby the lubrication department selects lubricants and hydraulic fluids which meet the requirements specified by the equipment manufacturer in the warranty. In some cases, the properties and characteristics are specified; in other cases a lubricant may be identified specifically by trade name. The lubrication staff is responsible to see that the correct product is selected, purchased and applied properly. The actual purchasing of lubricants and hydraulic fluids is done by the purchasing department. Application of the lubricants is typically done by the plant operators or maintenance department.

The second common method could be called the "buy by specification" practice. The lubrication department prepares and periodically updates, to reflect more stringent or changing requirements, a detailed lubricant "specification". These specifications reflect the equipment requirements and any additional or modified requirements determined from operating, maintenance and lubrication experience, and performance. A complete set of specifications for a single steel mill may include two to four page "spec sheets" for over 100 oils, greases, and hydraulic fluids. Every year or two the steel mill (via the purchasing department, and lubrication staff) requests competitive bids for the anticipated quantities of lubricants. Lubricant suppliers may offer an "off-the-shelf" product or a special product formulated for that particular steel mill. This lubricant purchasing practice can involve a major effort by the lubrication staff. One steel mill surveyed by PES purchases 120 different oils, greases, and hydraulic fluids from more than 20 different lubricant distributors or manufacturers. As is the case in the previously described purchasing method, actual equipment lubrication is performed by the plant operators or maintenance department.

APPENDIX B

HYDROCARBON STACK SAMPLING AND AMBIENT MONITORING ANALYSIS

1.0 STACK GAS EMISSION DETERMINATIONS

1.1 MASS FLOW RATE

56" 4-Stand Mill:

Stack gases molar flow rate = 236.82 lb. moles/min.

Hence, total hydrocarbons (as methane) emission rate =

$$236.82 \frac{\text{lb. moles}}{\text{min.}} \times \frac{60 \times 24 \times 365}{1} \frac{\text{min.}}{\text{yr.}} \times \frac{60 \text{ ppm}}{10^6} \times 16 \frac{\text{lb.}}{\text{lb./mole}} \times \frac{1}{2000} \frac{\text{ton}}{\text{lb.}}$$

$$= 59.7 \text{ ton/year}$$

80" 5-Stand Mill:

Stack gases molar flow rate = 258.42 lb. moles/min.

Hence, total hydrocarbons (as methane) emission rate =

$$258.42 \frac{\text{lb. moles}}{\text{min.}} \times \frac{60 \times 24 \times 365}{1} \frac{\text{min.}}{\text{yr.}} \times \frac{57 \text{ ppm}}{10^6} \times 16 \frac{\text{lb.}}{\text{lb./mole}} \times \frac{1}{2000} \frac{\text{ton}}{\text{lb.}}$$

$$= 61.9 \text{ ton/year}$$

1.2 MOISTURE CONTENT

$$B_{Wo} = \frac{V_{Wc}}{V_{Wc} + V_{Mc}} + B_{Wm}$$ (Federal Register Method--4, Eq.4-3)

B_{Wo} = Proportion of water vapor in the gas stream, by volume.

V_{Wc} = Volume of water vapor collected (standard conditions) ft^3.

V_{Mc} = Dry gas volume through meter (standard conditions) ft^3.

B_{Wm} = Approximate volumetric proportion of water vapor in the gas stream leaving the impingers $\cong$ 0.025.

Table B-1 PES SOURCE TEST DATA FORM

Plant: Inland Steel
Run No.: 80" Tandem Mill
Location: East Chicago, IN
Date: 12/20/77
Operator: PES

Ambient Temperature, ^{o}F: $68^{o}F$
Barometric pressure, in. Hg: 29.92
Assumed Moisture, %: 15%
Probe tip diameter, in.: 1/4"
Probe length, ft.: 9'

Reading Number Point	Every 10 Min. Clock Time	Dry Gas Meter, ft^3	Pitot in. H_2O P	Sampling Rate ft^3/min		Pump Vacuum, in. Hg Gauge	Impinger Temp. ^{o}F	HC PPM	Stack Temp. ^{o}F
				Desired	Actual				
1	10:00	019.76	0.20	0.977	0.85	6		170	103
2	10:10		0.20	0.437	0.41	2	9.0	200	92
3	10:20		0.20	0.425	0.44	1.5	9.0	180	100
4	10:30			0.436	0.42	1.5	9.0	150	96
5	10:40		0.225	0.466	0.44	1.5	9.0	130	89
6	10:50		0.22	0.46		2.0	9.0	110	88
7	11:00		0.22	0.46	0.44	2.0	9.0	90	92
8	11:10		0.20	0.44	0.44	2.0	9.0	70	98
9	11:20		0.20	0.424	0.44	2.0	9.0	70	100
10	11:30	066.45	0.20			2.0	9.0	60	96

Table B-2 PES SOURCE TEST DATA FORM

Plant: Inland Steel
Run No.: 56" Tandem Mill
Location: East Chicago, IN
Date: 12/19/78
Operator: PES

Ambient Temperature, °F: 68°F
Barometric pressure, in. Hg: 29.92
Assumed Moisture, %: 15%
Probe tip diameter, in.: 1/4"
Probe length, ft.: 9'

Reading Number Point	Every 10 Min. Clock Time	Dry Gas Meter, ft^3	Pitot in. H_2O P	Sampling Rate ft^3/min		Pump Vacuum, in. Hg Gauge	Impinger Temp. °F	HC PPM	Stack Temp. °F
				Desired	Actual				
1	5:10	962.96	0.15		0.5	6.0	15.0	0.0	82
2	5:20		0.15	0.377		3.0	14.0	35	75
3	5:30		0.175	0.41		4.0	10.0	45	80
4	5:40		0.175	0.40		3.0	10.0	44	90
5	5:50		0.18	0.41		3.0	9.0	47	80
6	6:00		0.15	0.38		2.0	9.5	38	80
7	6:10		0.175	0.406		3.0	9.5	47	86
8	6:20		0.17	0.40		2.5	9.5	40	86
9	6:30		0.20	0.43		2.5	10	45	86
10	6:40	1019.75	0.175			2.5	10	47	86

- 56" Mill:

To find volume of water vapor:

$$pV = nRT \qquad \text{Ideal gas equation}$$

$p = 29.92$ in Hg

$$n = 222 \text{ ml} \times 1 \frac{\text{gm}}{\text{ml}} \times \frac{1}{453.5} \frac{\text{lb}}{\text{gm}} \times \frac{1}{18} \times \frac{\text{lb mole}}{\text{lb}}$$

$= 0.0271959$ lb moles

$R = 21.83$ in Hg - ft^3/lb mole - ^{o}R

$T = 32^oF + 460 = 492^oR$

$$V = \frac{nRT}{p} = \frac{0.0271959 \times 21.83 \times 492}{29.92}$$

$= 9.7624919 \text{ ft}^3$

i.e., $V_{Wc} = 9.7624919 \text{ ft}^3$

$$V_{Mc} = 56.79 \times \frac{492}{511.2}$$

$= 54.657 \text{ ft}^3$ (dry gas volume through meter)

Hence, $$B_{Wo} = \frac{9.7624919}{9.7624919 + 54.657}$$

$= 0.1515$

i.e., 15.2 % moisture content (by volume) -- 56"

- 80" Mill:

To find volume of water vapor:

$$pV = nRT$$

$p = 29.92$ in Hg

$$n = 228 \text{ ml} \times \frac{1 \text{ gm}}{\text{ml}} \times \frac{1}{453.6} \frac{\text{gm}}{\text{lb}} \times \frac{1}{18} \frac{\text{lb mole}}{\text{lb}}$$

$= 0.0279309$ lb moles

R = 21.83 in. Hg - ft^3/lb. mole - R^o

T = $32^oF + 460 = 492^oR$

$$V = \frac{nRT}{p} = \frac{0.0279309 \times 21.83 \times 492}{29.92}$$

$$= 10.026334 \text{ ft}^3$$

$$V_{Mc} = 46.69 \times \frac{492}{507.6}$$

= 45.255083 ft^3 (dry gas volume through meter)

Hence,

$$B_{Wo} = \frac{10.026334}{10.026334 + 45.255083}$$

$$= 0.181$$

i.e., 18.1% moisture content (by volume) -- 80"

1.3 STACK GAS VELOCITY

a) By EPA Method:

$$(V_S) \text{ avg.} = Kp\ Cp\ (\quad P) \text{ avg.} \quad \frac{(T_S) \text{ avg.}}{P_S\ M_S}$$

(Federal Register -- EPA Method 2, Eq. 2-2)

where,

(V_S) avg. = Stack gas velocity, ft./sec.

Kp = $85.48 \frac{\text{ft.}}{\text{sec.}} \quad \frac{\text{lb.}}{\text{lb. mole} - {}^oR}^{1/2}$

Cp = Pitot tube coefficient, dimensionless = 0.85 (assumed)

(T_S) avg. = Average absolute stack gas temperature ^oR

(P) avg.= Average velocity head of stack gas, in H_2O

P_S = Absolute stack gas pressure, in. Hg

M_S = Molecular weight of stack gases (wet basis), lb./lb. mole

= $Md\ (1-B_{Wo}) + 18\ B_{Wo}$

= $28.84\ (1 - 0.152) + (18(0.152) = 27.19$ lb./lb. mole

Md = Stack gas dry molecular weight (Method 3)

= 28.84 lb./lb. mole

B_{Wo} = Proportion by volume of water vapor in the gas stream (Method 4)

AVERAGE STACK GAS VELOCITY FOR 56" MILL

Kp = 85.48

Cp = 0.85 (assumed

M_S = $28.84\ (1 - 0.152) + 0.152(18) = 27.19$ lb./lb. mole

P avg. = 0.17 in. H_2O

T_S avg. = $83.1\ ^oF + 460 = 543.1\ ^oR$

P_S = 29.92 in. Hg

$$(V_S)\ \text{avg.} = 85.48 \times 0.85 \times\ 0.17\ \times \frac{83.1 + 460}{29.92 \times 27.19}$$

= 24.48 ft./sec. (Method 2, Eq. 2-2)

AVERAGE STACK GAS VELOCITY FOR 80" MILL

(T_S) avg. = $95.4 + 460 = 555.4\ ^oR$

(P) avg. = 0.2065 in. H_2O

P_S = 29.92 in. Hg

M_S = $28.84\ (1 - 0.181) + 0.181(18)$

= 26.878

$$(V_S)\ \text{avg.} = 85.48 \times 0.85 \times\ 0.2065\ \times \frac{555.4}{29.92 \times 26.878}$$

= 27.44 ft./sec. (By Method 2, Eq. 2-2)

b) By South Coast Air Quality Management District Method

$$V = 2.9 \quad P \cdot T_S$$

For 56" Mill:

$$(\quad P)_{avg.} = 0.4123 \text{ in. } H_2O$$

$$T_S = 83.1 + 460 = 543.1^oR$$

Hence,

$$V = 2.9 \quad 0.17 \times 543.1$$

$$= 27.84 \text{ ft./sec.}$$

For 80" Mill:

$$(\quad P)_{avg.} = 0.4544 \text{ in. } H_2O$$

$$T_S = 95.4 + 460 = 555.4^oR$$

$$V = 2.9 \quad 0.2065 \times 555.4$$

$$= 31.05 \text{ ft./sec.}$$

For calculating volumetric flow rate in each of the 56" Tandem and 80" Tandem mills, the vrlocity calculated by SCAQMD method was also considered.

1.4 VOLUMETRIC FLOW RATE OF STACK GAS (Stack Air)

56" Cold Strip Tandem Mill:

$V = v \times a$

where,

V = volumetric flow rate, ft^3/sec.

v = avg. stack gas velocity, ft./sec.

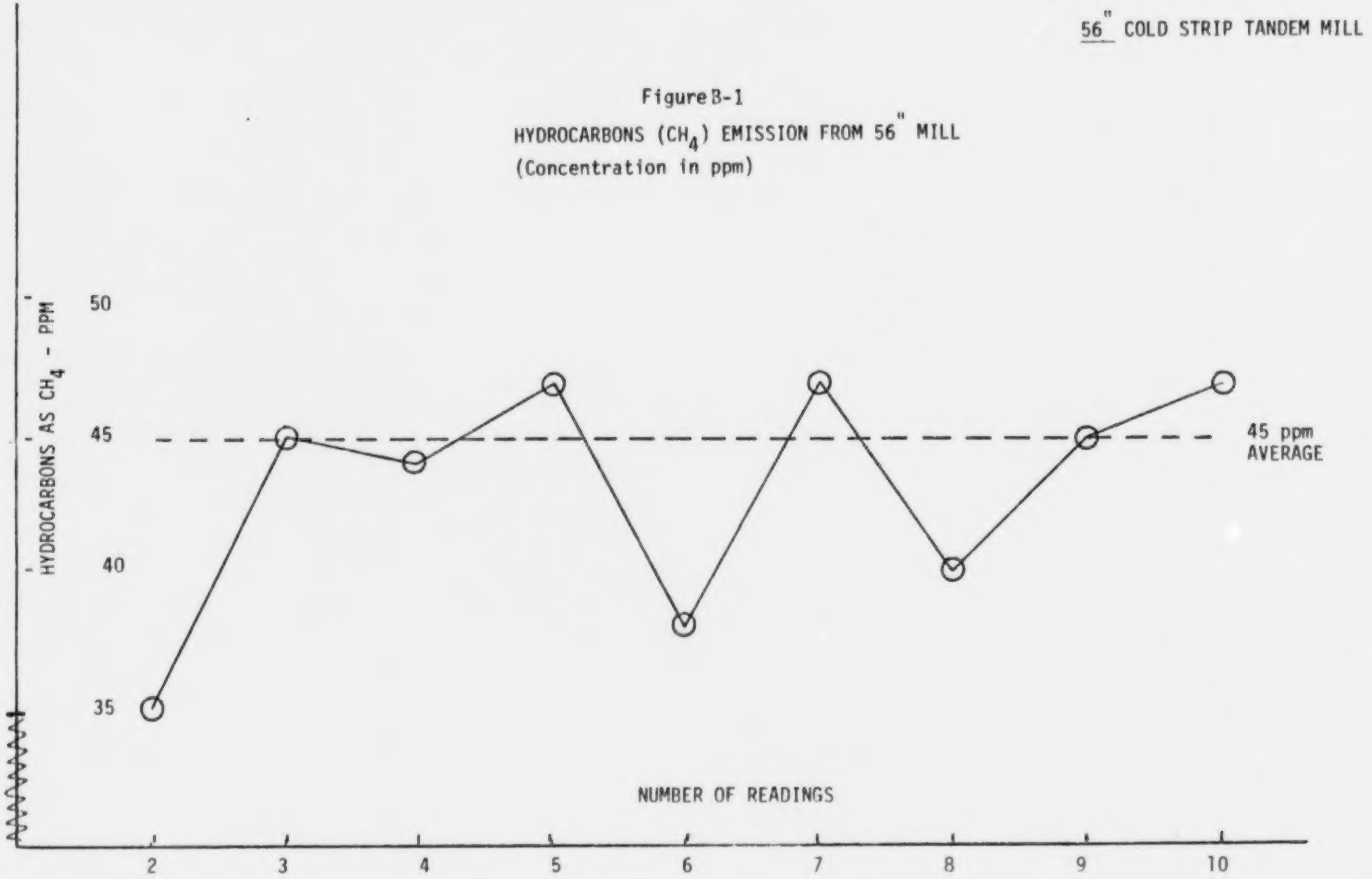
a = cross section area of 56" stack, ft^3

56" COLD STRIP TANDEM MILL

Figure B-1

HYDROCARBONS (CH_4) EMISSION FROM 56" MILL

(Concentration in ppm)



For 56" Mill:

$v = 27.84$ ft/sec

$a = 56.19$ ft^2

Hence,

$V = 27.84 \times 56.19$

$= 1,564$ ft^3/sec

Molar flow rate of stack gases through 56" mill stack:

$pV = nRT$

p = stack pressure

= 29.92 in. Hg

V = volumetric flow rate

= 1,564 ft^3/sec

= 93,840 ft^3/min

R = gas constant

= 21.83 in. Hg ft^3/lb mole - $^{\circ}$R

T = absolute temperature of stack gases

= 543.1 $^{\circ}$R

Hence,

$$\text{Molar flow rate} = \frac{pV}{RT} = \frac{29.92 \times 93,840}{21.83 \times 543.1}$$

$$= 236.82 \text{ lb mole/min}$$

- 80" Cold Strip Tandem Mill:

Volumetric flow rate of stack gases through 80" mill:

$V = v \times a$

where v = average stack gas velocity, ft/sec

a = cross section area of 80" stack, ft^2

V = Volumetric flow rate, ft^3/sec

For 80" Mill:

$v = 31.05$ ft/sec

$a = 56.19\ \text{ft}^2$

Hence,

$V = 31.05 \times 56.19$

$= 1{,}744.7\ \text{ft}^3/\text{sec}$

$= 104{,}682\ \text{ft}^3/\text{min}$ (this tallies with 100,000 CFM exhaust fan capabity)

Molar flow rate of stack gases through 80" mill stack:

$pV = nRT$

p = stack pressure

= 29.92 in. Hg

V = Volumetric flow rate

$= 1{,}744.7\ \text{ft}^3/\text{sec}$

$= 104{,}682\ \text{ft}^3/\text{min}$

R = gas constant

$= 21.83$ in. Hg - ft^3/lb mole - $^{\circ}\text{R}$

T = absolute temperature

$= 555.2\ ^{\circ}\text{R}$

Hence,

$$\text{Molar flow rate} = \frac{pV}{RT} = \frac{29.92 \times 104{,}682}{21.83 \times 555.2}$$

$= 258.42$ lb moles/min

Since the velocity calculated by the SCAQMD method was greater than those calculated by the EPA method by approximately ten percent, the SCAQMD method was chosen for further calculations. This choice assumed that all emission calculation would be on a worst case basis (i.e., highest mass flow rate).

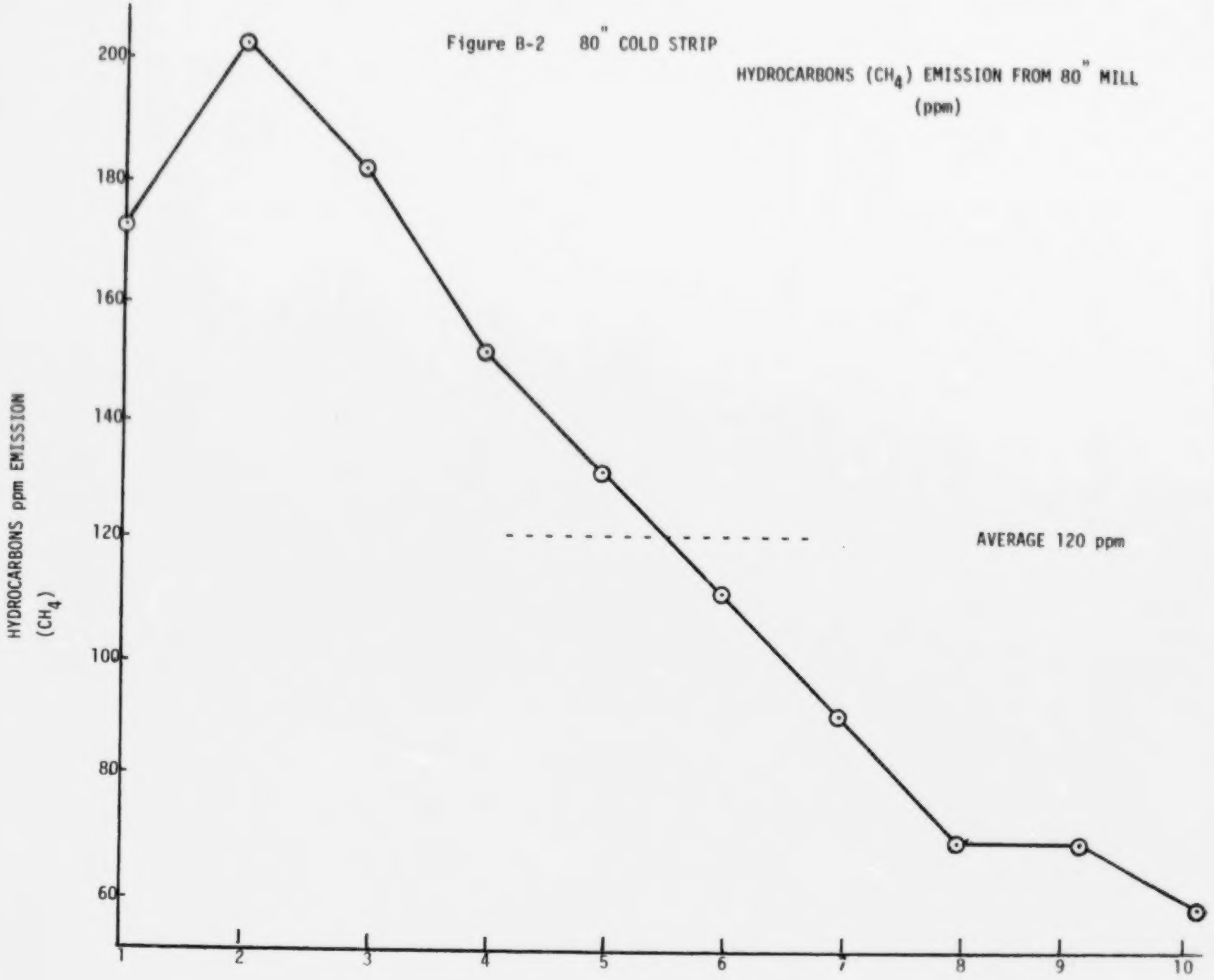


Figure B-2 80" COLD STRIP

HYDROCARBONS (CH_4) EMISSION FROM 80" MILL
(ppm)

1.5 AVERAGE HC CONCENTRATION

Average total hydrocarbon (as methane) concentration in ppm averaged over the entire sampling period for both the 56 inch and the 80 inch mill were:

Mill	Average HC Concentration (as Methane)
56 inch 4-Stand	45 ppm (measured on the Analyzer)
80 inch 5-Stand	120 ppm (measured on the Analyzer)

After the sampling was completed, the analyzer was calibrated with a known concentration (989 ppm) of propane. The calibration arrangement is shown in Figure B-3 which contains the formula for calculating actual HC concentrations.

1.6 CALIBRATION OF THE HC ANALYZER (56 inch mill):

(1) Propane calibration gas, ppm = 989 ppm

(2) Rotameter flow (used during calibrating the Analyzer)

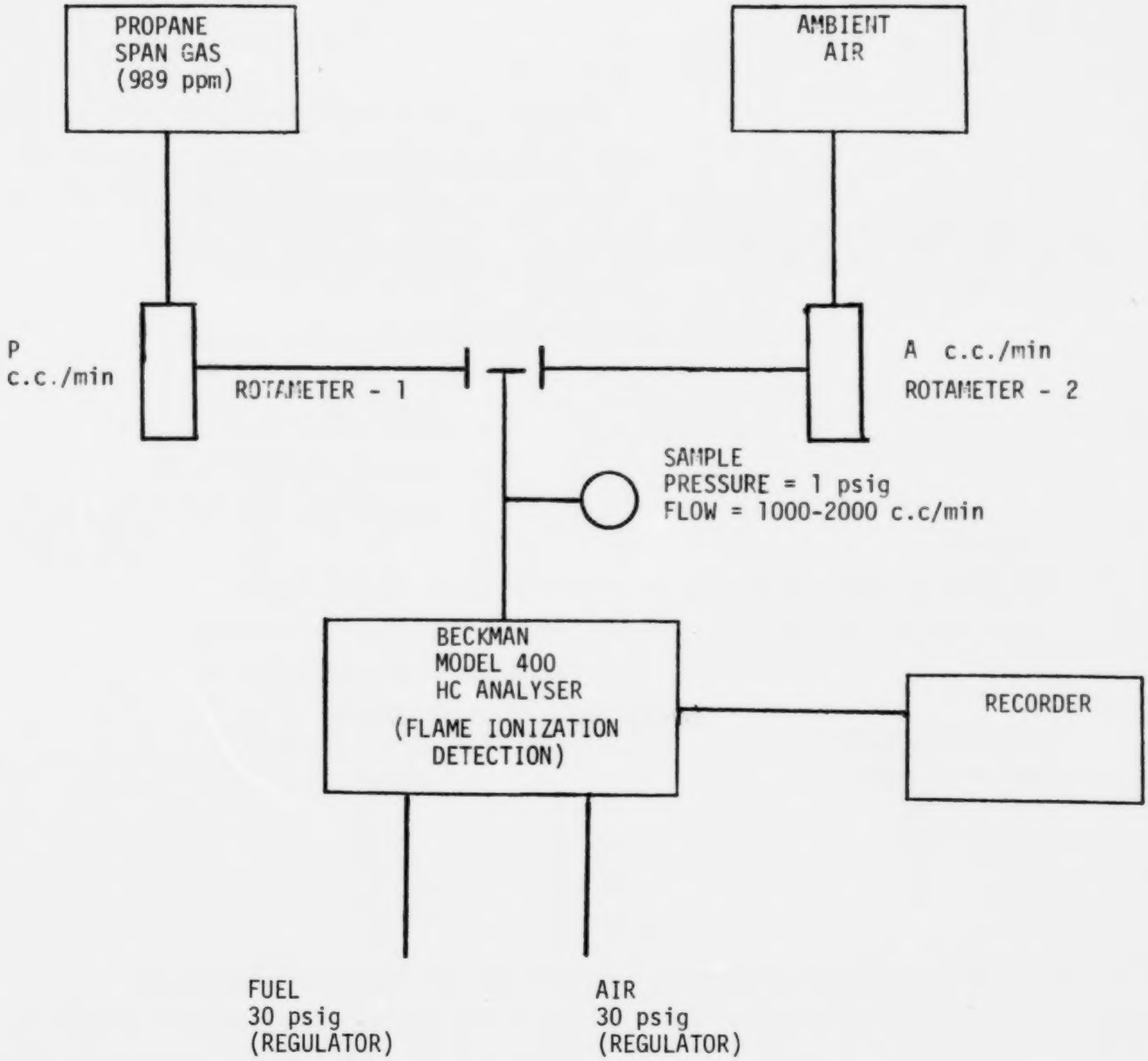
Propane (Rotameter-1)	Air (Rotameter-2)
7.6	11.5
7.6	14.6
7.5	14.9
7.6	13.4

(3) Actual flow:

Calibration curves supplied by the manufacturer for these two rotameters were referred to calculate actual flow in millimeters/minute for propane and ambient air.

Actual Flow:

Propane (ml/min) (Rotameter-1)	Air (ml/min) (Rotameter-2)
49	2065
49	2455
48	2490
49	2305


PROPANE
SPAN GAS
(989 ppm)
AMBIENT
AIR
P
c.c./min
ROTAMETER - 1
A c.c./min
ROTAMETER - 2
SAMPLE
PRESSURE = 1 psig
FLOW = 1000-2000 c.c/min
BECKMAN
MODEL 400
HC ANALYSER
(FLAME IONIZATION
DETECTION)
RECORDER
FUEL
30 psig
(REGULATOR)
AIR
30 psig
(REGULATOR)

$$\text{ACTUAL CONCENTRATION} = \text{ANALYSES READING} \times \left(\frac{\text{P c.c}}{\text{P c.c} + \text{A c.c}}\right)$$

Figure B-3 CALIBRATION OF BECKMAN MODEL 400 HC ANALYSER (FID)

(4) Actual concentration of propane:

Sample calculation on Reading No. 1

Actual concentration of propane =

$$\text{Propane calibration gas, pmm} \times \frac{\text{Propane actual flow, mls}}{\text{Propane actual flow, mls} + \text{Air actual flow, mls}}$$

Hence, actual concentration of propane =

$$989 \times \frac{49}{49 + 2065}$$

= 22.9 ppm Propane

= 68.7 ppm Methane

Actual propane concentrations for all three readings were calculated and tabulated against the Analyzer readings as was shown in the above sample calculation.

Propane Actual Concentration (ppm)	Analyzer Reading (as shown on scale)
22.9	85
19.4	43
18.7	10
20.6	65

The calibration curve for the analyzer (Propane actual concentration versus Analyzer reading) was prepared using the above calucated values (See Figure B-4).

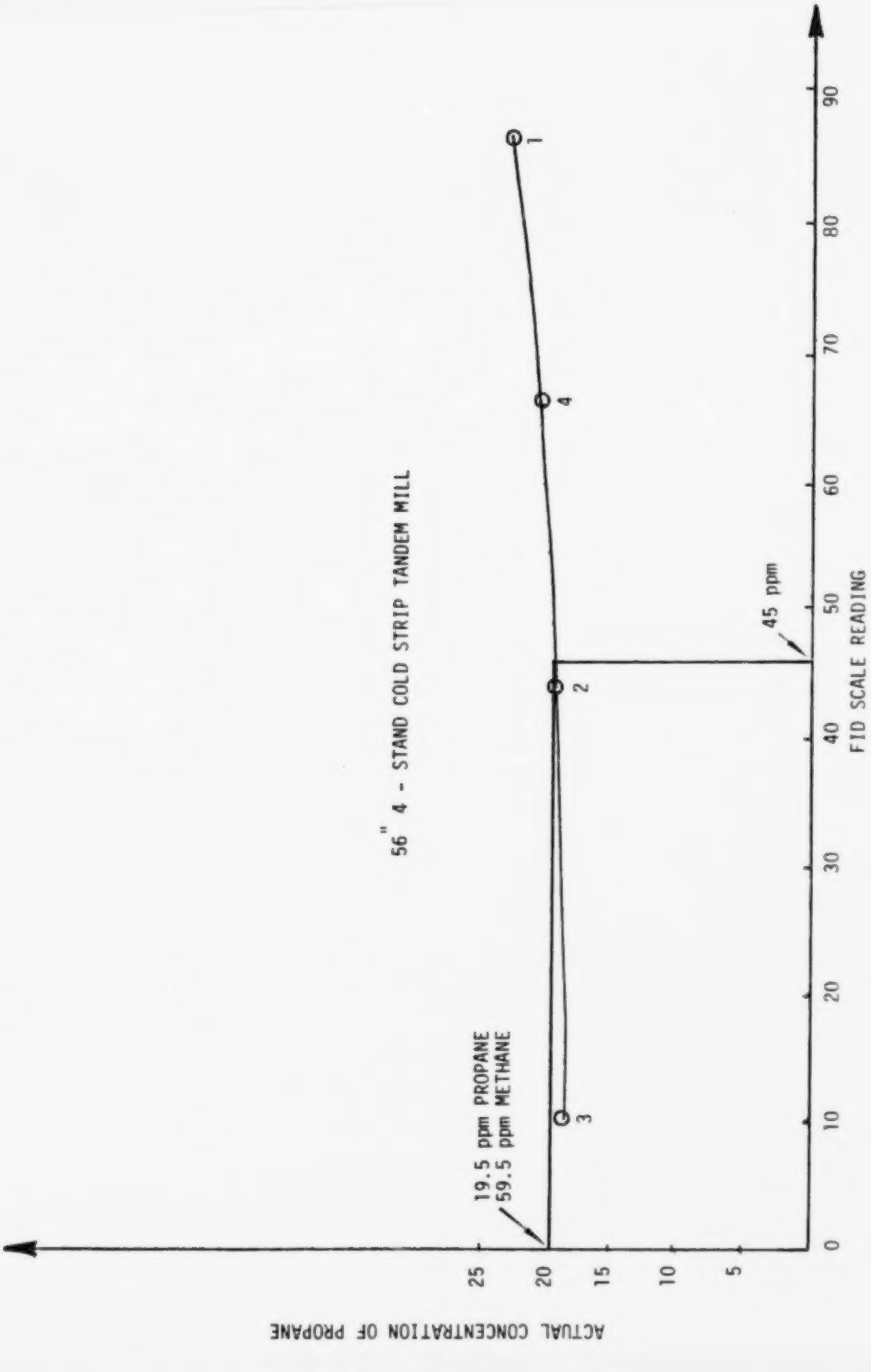
1.7 CALIBRATION OF THE HC ANALYZER (80 inch mill):

(1) Propane calibration gas, ppm: 989 ppm

(2) Rotameter flow (used during calibrating the Analyzer):

The following, actual propane concentration for all three readings were calculated and tabulated:

Propane Actual Concentration (ppm)	Analyzer Reading (as shown on scale) (ppm)
18.2	26
18.8	84
18.1	58



56" 4 - STAND COLD STRIP TANDEM MILL

Figure B-4

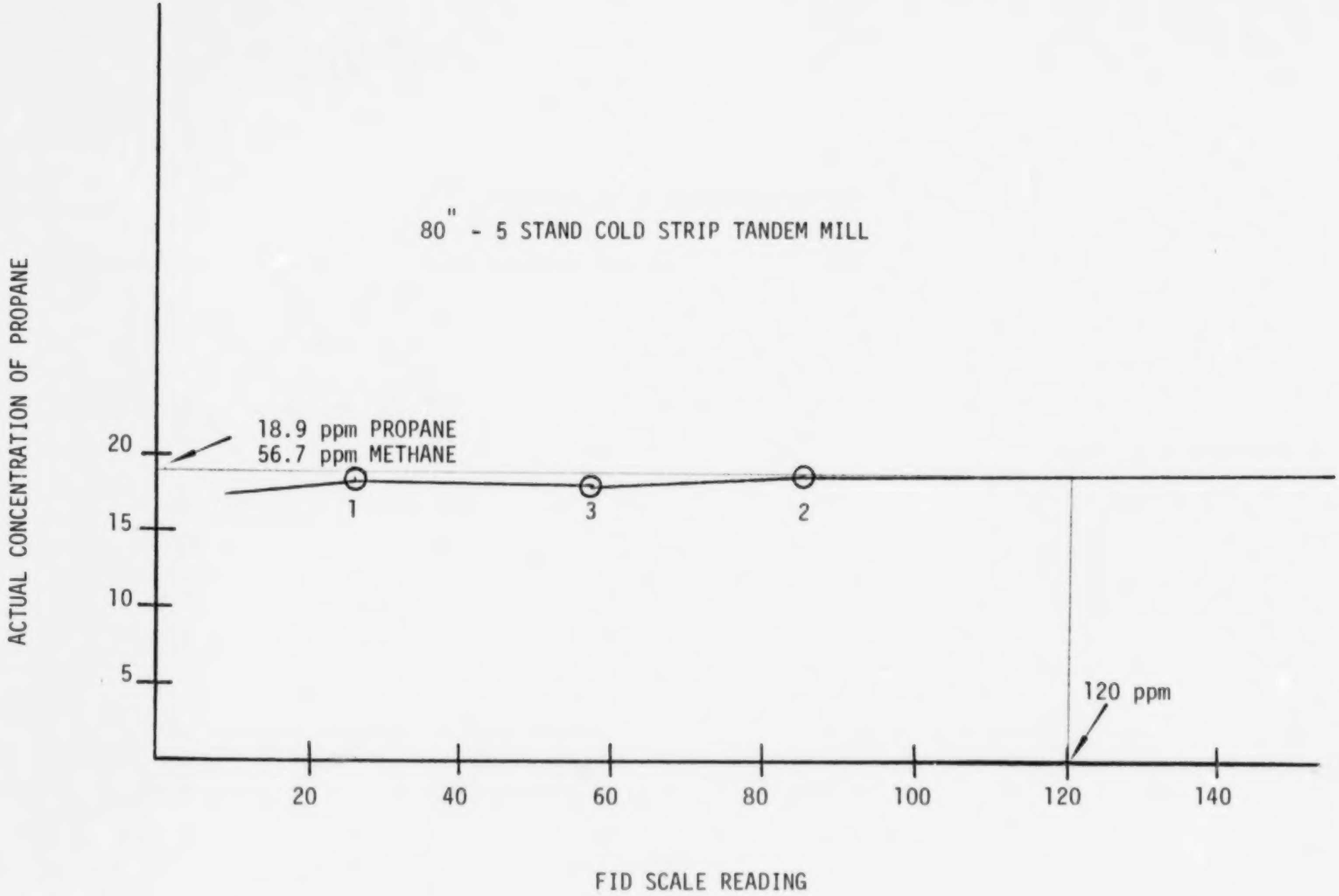

80" - 5 STAND COLD STRIP TANDEM MILL
ACTUAL CONCENTRATION OF PROPANE
18.9 ppm PROPANE
56.7 ppm METHANE
20
15
10
5
1
3
2
120 ppm
20
40
60
80
100
120
140
FID SCALE READING

Figure B-5

Propane	Air
(Rotameter-1)	(Rotameter-2)
7.3	14.8
7.5	14.8
7.2	14.6

(3) Actual flow:

Calibration curves supplied by the manufacturer or these two rotameters were referred to calculate actual flow in millimeters/minute for propane and ambient air.

Actual Flow:

Propane (ml/min)	Air (ml/min)
(Rotameter-1)	(rotameter-2)
46.5	2480
48	2480
45.5	2445

(4) Actual concentration of propane:

Sample calculation on Reading No. 1

Actual concentration of propane =

$$\text{Propane calibration gas, ppm} \times \frac{\text{Propane actual flow, mls}}{\text{Propane actual flow, mls + Air actual flow, mls}}$$

Hence, actual concentration of propane =

$$989 \times \frac{46.5}{46.5 + 2480}$$

= 18.2 ppm Propane

= 54.6 ppm Methane

Table B-3

Summary: 56" Mill Sample

Summary of Hydrocarbon Data:

Sample	% Total Oil	% Aliphatic Hydrocarbons	% Olifinic Hydrocarbons	% Polar Lipids*
Air Sample No. 1	---	33.0	38.8	28.1
Air Sample No. 2	---	26.6	33.3	40.0
Water Wash	---	27.1	32.2	39.6
Acetone Wash	---	27.1	33.3	39.6
Emulsion Sample	6.0	27.1	33.3	39.6

Table B-4

Summary: 80" Mill Sample

Summary of Hydrocarbon Data:

Sample	% Total Oil	% Aliphatic Hydrocarbons	% Olifinic Hydrocarbons	% Polar Lipids*
Air Sample No. 3	---	32.7	39.1	28.1
Water Wash	---	32.7	39.0	28.3
Acetone Wash	---	32.6	39.0	28.2
Emulsion Sample	2.8	32.7	39.1	28.2

*Calculated value.

Table B-5

# 56 inch Mill Air Sample #1 6:05 P.M.

Total Oil	12.1 ugs
Total Aliphatic Hydrocarbons	4.0 ugs
Total Olifinic Hydrocarbons	4.7 ugs
Total Polar Lipids Materials	3.4 ugs

Aliphatic Hydrocarbons		% of Total Aliphatic Hydrocarbons
C-14	0.23 ugs	5.8 %
C-15	0.30 ugs	7.6 %
C-16	0.48 ugs	12.1 %
C-17	0.54 ugs	13.6 %
C-18	0.61 ugs	15.4 %
C-19	0.41 ugs	10.4 %
C-20	0.22 ugs	5.6 %
C-21	0.33 ugs	8.3 %
C-22	0.23 ugs	5.8 %
C-23	0.18 ugs	4.5 %
C-24	0.13 ugs	3.3 %
C-25	0.15 ugs	3.8 %
C-26	0.15 ugs	3.8 %
C-28	0.10 ugs	< 2.0 %
C-30	0.10 ugs	< 2.0 %
C-32	0.10 ugs	< 2.0 %
C-34	0.10 ugs	< 2.0 %
C-36	0.10 ugs	< 2.0 %
C-38	0.10 ugs	< 2.0 %

Table B-6

# 80 inch Mill Air Sample #3

Total Oil	80.7 ugs
Total Aliphatic Hydrocarbons	26.4 ugs
Total Olifinic Hydrocarbons	31.6 ugs
Total Polar Lipids Materials	22.7 ugs

Aliphatic Hydrocarbons			% of Total Aliphatic Hydrocarbons
C-14	1.00	ugs	< 2.0 %
C-15	1.74	ugs	6.6 %
C-16	1.61	ugs	6.1 %
C-17	2.44	ugs	9.2 %
C-18	2.81	ugs	10.6 %
C-19	3.79	ugs	14.3 %
C-20	2.59	ugs	9.8 %
C-21	2.00	ugs	7.6 %
C-22	1.25	ugs	4.7 %
C-23	1.83	ugs	6.9 %
C-24	1.74	ugs	6.6 %
C-25	1.56	ugs	5.9 %
C-26	1.28	ugs	4.8 %
C-28	1.78	ugs	6.7 %
C-30	1.00	ugs	< 2.0 %
C-32	1.00	ugs	< 2.0 %
C-34	1.00	ugs	< 2.0 %
C-36	1.00	ugs	< 2.0 %
C-38	1.00	ugs	< 2.0 %

Table B-7

#56 inch Mill Emulsion Sample

Total Oil in Oil/Water Emulsion	6.0	%
% Aliphatic Hydrocarbons in Oil	27.1	%
% Olifinic Hydrocarbons in Oil	33.3	%
% Polar Lipid Materials in Oil	39.6	%

Aliphatic Hydrocarbons			% of Total Aliphatic Hydrocarbons	
C-14	122	mgs	16.3	%
C-15	288	mgs	30.4	%
C-16	91	mgs	12.1	%
C-17	66	mgs	8.8	%
C-18	60	mgs	8.0	%
C-19	50	mgs	6.7	%
C-20	37	mgs	4.9	%
C-21	20	mgs	2.7	%
C-22	21	mgs	2.8	%
C-23	18	mgs	2.4	%
C-24	14	mgs	1.9	%
C-25	13	mgs	1.7	%
C-26	5	mgs	0.7	%
C-28	4	mgs	< 0.5	%
C-30	1	mgs	< 0.5	%
C-32	1	mgs	< 0.5	%
C-34	1	mgs	< 0.5	%
C-36	1	mgs	< 0.5	%
C-38	1	mgs	< 0.5	%

Table B-8

#80 inch Mill Emulsion Sample

Total Oil in Oil/Water Emulsion	2.8	%
% Aliphatic Hydrocarbons in Oil	32.7	%
% Olifinic Hydrocarbons in Oil	39.1	%
% Polar Lipid Materials in Oil	28.2	%

Aliphatic Hydrocarbons			% of Total Aliphatic Hydrocarbons
C-14	141	mgs	19.0 %
C-15	144.9	mgs	19.5 %
C-16	65.5	mgs	8.8 %
C-17	54.2	mgs	7.3 %
C-18	80.0	mgs	10.8 %
C-19	51.7	mgs	7.0 %
C-20	42.8	mgs	5.8 %
C-21	29.0	mgs	3.9 %
C-22	53.6	mgs	7.2 %
C-23	41.6	mgs	5.6 %
C-24	17.6	mgs	2.4 %
C-25	5.7	mgs	0.8 %
C-26	6.3	mgs	0.8 %
C-28	9.4	mgs	1.3 %
C-30	1	mgs	0.5 %
C-32	1	mgs	0.5 %
C-34	1	mgs	0.5 %
C-36	1	mgs	0.5 %
C-38	1	mgs	0.5 %